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Orthotic Management of Paraplegia

Volume 11, Number 2 Spring, 1987

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CONTENTS

Volume 11, Number 2 **Spring, 1987**

Orthotic Management of Paraplegia

FEATURES

ADVERTISER'S INDEX

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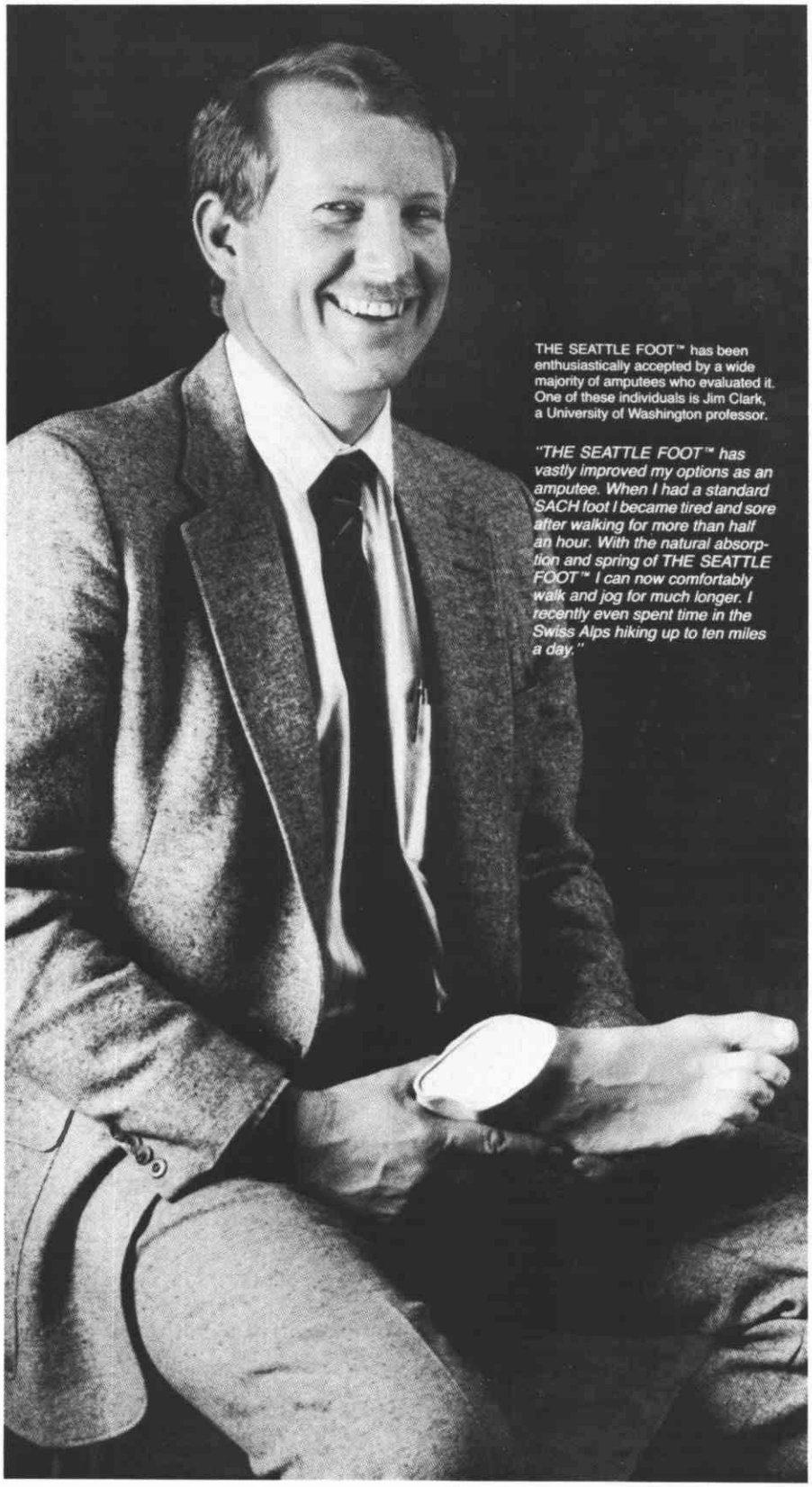

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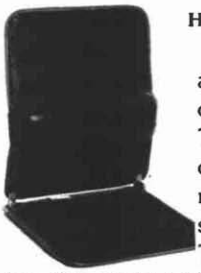

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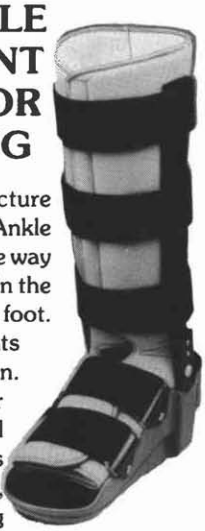

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Letters to the Editor

Dear Editor:

I think that the Winter, 1987 issue of *Clinical Prosthetics and Orthotics* turned out nicely, but am dismayed to see that editorial policy has dictated that "residual limb" and "limb" be used instead of "stump." You will recall the editorial you published some years ago in which I gave what I believe are very valid reasons for not using "residual limb" in scientific and technical publications. I haven't changed my mind on this and I wouldn't want the readers of *C.P.O.* to think that I have.

I have no quarrel with clinicians avoiding the use of "stumps" in dealing with patients, but "residual limb" and simply "limb" are usually thought of, quite correctly, as the unaffected one and at best is ambiguous if not outright misleading, two things that should be avoided at all costs in scientific and technical writing.

In my opinion the use of "residual limb" is an affectation that should be avoided by those who should know better.

Sincerely,
A. Bennett Wilson, Jr.

AUTHOR INFORMATION

Clinical Prosthetics & Orthotics

As professionals, we are obligated to do what we can to advance the state-of-the-art and share new developments with our colleagues. The most efficient way to transfer information, and the way that has the greatest impact, is through the written word. But, for many professionals, writing is a task that often becomes monumental to the point that we succumb to inertia. Writing, however, is not such a monumental task if we break it down into smaller, simpler tasks which we can complete one at a time.

The initial and most difficult problem every writer faces is how to organize the material. The quickest way to organize material is through the use of an outline. In its most basic form, an article is divided into three parts—introduction, body, and conclusion. The introduction states the subject and gives pertinent background information that is necessary in order to understand the topic. The main body of the article is the intent to inform and answer a variety of questions. The body can include subheads, such as review of literature, method, clinical materials, discussion, and results. The conclusion restates the main points presented in the article.

Clinical Prosthetics and Orthotics addresses broad, philosophical issues, and as such invites a more subjective style. Each issue of *C.P.O.* centers on a main topic. Usually, an issue will contain a lead article, an editorial, and one or more technical articles pertaining to the topic. Authors are solicited by the Academy editorial board; however, *C.P.O.* also accepts unsolicited articles. Unsolicited articles need not cover the topic at hand and may be of a more technical and objective nature. All articles are submitted to the editor, a professional in the field, who checks every article for accuracy, terminology, format, and references. The articles are then forwarded to the publications staff at the Academy National Office for production and printing.

The chosen topics for *Clinical Prosthetics and Orthotics,* Volume 11, Number 4 through Volume 12, Number 3, and deadlines for submission are as follows:

Volume 11, Number 4	"Quadraplegia" Deadline: July 1, 1987
Volume 12, Number 1	"Prosthetic Management of the Partial Foot and Symes Amputations" Deadline: September 1, 1987
Volume 12, Number 2	"Orthotic Management of the Foot" Deadline: December 1, 1987
Volume 12, Number 3	"Disarticulation Amputations" Deadline: March 1, 1988

Please remember that although these are the chosen topics for these particular issues, we gladly welcome submissions on other topics. Please feel free to contact the National Office if you have any questions on whether your article would be appropriate for *C.P.O.*

If you have an article that has been previously published in another scientific journal and think it may be appropriate for *C.P.O.,* please let us know.

Submit articles to: Charles Pritham, CPO, Editor, c/o Durr-Fillauer Medical, Inc., Orthopedic Division, P.O. Box 5189, Chattanooga, Tennessee 37406.

Questions should be submitted to: Sharada Gilkey, Managing Editor, Academy National Office, 717 Pendleton Street, Alexandria, Virginia 22314; or call (703) 836-7118.

P.S. Author's kits are made available upon request, free of charge. Kits include manuscript guidelines, a patient permission form, reprint information, a reprint permission form, and information on prizes for published articles.

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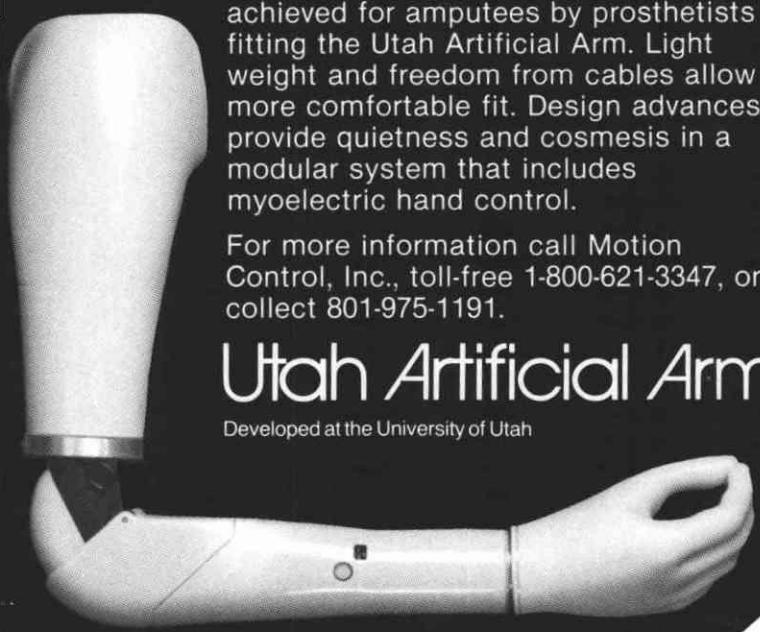

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Clinical Prosthetics and Orthotics, Vol. 11, No. 2, pp. 66–73

A Physiologic Rationale for Orthotic Prescription in Paraplegia

by Robert L. Waters, M.D.
Leslie Miller, R.P.T.

INTRODUCTION

A difficult clinical decision to be made when treating a paraplegic patient is deciding if walking is a realistic goal, if orthoses should be prescribed, and what the functional outcome will be. It has been demonstrated that the energy expenditure for paraplegics, utilizing a crutch assisted swing-through gait pattern, is markedly elevated. Many patients have learned to walk with crutches and orthoses, but discontinued their use after discharge from a rehabilitation center.[2,3,4] Studies of other forms of bracing also reveal elevated energy expenditure.[12]

In this review, we will describe the indications for prescribing ankle-foot orthoses and knee-ankle-foot orthoses. We will then outline the criteria used at Rancho Los Amigos Medical Center to determine whether or not a paraplegic is a candidate for ambulation. These criteria are based on the results of energy expenditure measurements of 150 patients with traumatic paraplegia.[10] Further investigation of the data collected revealed that the proprioception level or pattern seemed a reliable indicator of which patients would achieve ambulation, while muscle function seemed to determine the quality of their ambulation. These results have helped us to develop guidelines for projecting the functional outcome of ambulation of paraplegics.

ORTHOTIC PRESCRIPTION

The goal of orthotic management in paraplegia is to provide the external support necessary to compensate for the motor and sensory deficits. Joint range of motion, muscle strength, proprioception, sensation, and spasticity are evaluated when determining the orthotic prescription.

Knee-Ankle-Foot Orthosis (KAFO)

Quadriceps strength less than "Fair+" on manual muscle testing is the most common indication for a KAFO. The KAFO is locked at the knee while walking. Although some patients with less than "Fair+" strength are able to ambulate a short distance without a locked knee (knee stabilization), knee instability usually occurs after a few steps. The exception is the patient with severe quadriceps spasticity which maintains the knee in extension, eliminating the need for external support.

Another indication for a KAFO is impaired or absent knee proprioception. The lack of proprioception can result in knee instability even when the quadriceps strength is "Fair+" or greater, as the patient is unable to monitor joint position. If light touch sensation is present on the front of the thigh, a KAFO which allows knee flexion is usually sufficient to control the knee. The anterior stop of the knee mechanism limits extension at 180 degrees and the patient feels pressure from the anterior thigh cuff. In this regard, the brace serves as a transducer that converts proprioception (which is not perceived) into pressure (which is perceived).

The final indication for extending bracing above the knee is a severe hyperextension thrust during stance. Paraplegics whose gait is

characterized by a hyperextension thrust may develop ligamentous instability, due to attenuation of the posterior cruciate ligament and posterior knee capsule resulting in hyperextension deformity.

Range of motion at the hip from 0 degrees of extension to 110 degrees of flexion should be present. In the absence of hip extensor muscles, full hip extension range is necessary to allow the patient to lean backwards and move the center of gravity of the trunk posterior to the hip joint (Figure 1). Hip flexion to 110 degrees, with the knee extended, enables the patient to come to standing with locked KAFO's and rise from the ground after a fall. Full knee extension is required for optimal fit.

Ten degrees of dorsiflexion at the ankle is the minimum necessary for unassisted upright balance (Figure 1). Normal proprioception in at least one hip also facilitates unassisted standing.

Inability to meet the joint range requirements described above commonly occurs and is most often due to spasticity or contracture. If satisfactory orthotic fit and posture cannot be achieved, a physical therapy regime that includes stretching exercises or serial casting is often successful when spasticity is mild and the deformity is not longstanding. When severe spasticity or deformity is present, or the deformity has been present for an extended time, the patient should be referred to an orthopedic surgeon.

Good trunk strength is necessary to maintain an erect posture in the standing position without excessive weight bearing in the arms. High level paraplegics without adequate trunk strength must exert a strong upwards force by the arms throughout the entire gait cycle to prevent forward collapse and accomplish forward progression. This contributes to the high energy demand. (All swing-through gait candidates are required to perform 50 consecutive dips on parallel bars to insure they have sufficient upper extremity strength and endurance.)

Ankle-Foot Orthosis (AFO)

Quadriceps strength greater than "Fair" should be present to stabilize the knee if an AFO is prescribed. The patient must also have adequate hip flexion strength to swing the leg forward to achieve a reciprocal gait pattern. The indications for AFO are numerous and include any or all of the following: plantarflexion strength less than "Good," dorsiflexion strength less than "Fair," impaired ankle proprioception, and moderate to severe plantarflexion spasticity.

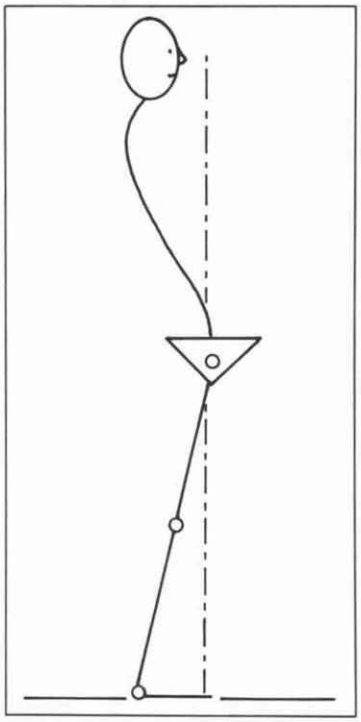

Figure 1. Standing posture.

During normal walking, the plantarflexors are active during the stance phase of gait to prevent excessive forward advancement of the tibia. As a result of forward momentum, the knee passively extends as the body advances forward over the stabilized tibia, and the demand placed on the quadriceps is minimal. Customary manual muscle testing methods fail to place a sufficient load on the plantarflexors to evaluate the force required during gait. The strength required to provide ankle and knee stability is present in patients who can perform 15 to 20 toe raises on one leg. Failure to provide adequate orthotic stabilization of the ankle in patients with inadequate plantarflexion strength may result in ankle instability and knee instability, if the quadriceps and/or hip extension strength is also inadequate.

Knee wobble can be a sign of impaired ankle proprioception and/or weakness. This can be eliminated by an AFO with a rigid ankle or anterior ankle stop, which provides distal stability and kinesthetic information via the calf cuff.

An AFO may be utilized to hold the ankle in the neutral position when dorsiflexion strength is impaired or there is excessive plantarflexion spasticity. When spasticity is severe, it may not be possible to maintain the foot in neutral, and the patient should be referred to an orthopedic surgeon if non-operative measures prove inadequate.

When the ankle is held in a rigid orthosis, ankle stability is gained during midstance. However, a forward thrust is imposed, forcing the knee into flexion at the moment of heel contact. (This knee flexion torque is generated because the rigidly immobilized ankle rotates forward about the point of heel contact.) During normal gait, this torque is avoided by ankle plantarflexion, minimizing the effect of the heel lever.

There are two courses of action available to provide ankle stability during stance, while still maintaining knee stability at heel strike. If the patient has "Fair+" or better ankle dorsiflexion strength and intact proprioception, we fit a metal AFO with a double adjustable ankle joint. A set screw in the anterior channel provides an adjustable stop that prevents excessive dorsiflexion. The posterior stop is left open to allow free ankle plantarflexion. Springs can be added posteriorly if dorsiflexion strength is less than "Fair+." The advantage gained is that restriction of motion during terminal stance is maintained while the normal plantarflexion motion during heel contact is preserved, avoiding the undesired knee flexion torque. If the patient has less than "Fair" dorsiflexors or absent proprioception at the ankle, then the ankle is locked and either metal or plastic is used. To avoid the excessive knee flexion torque when the AFO is locked, the heel of the shoe is undercut. This decreases the heel lever and, thus, the knee flexion torque.

ORTHOSIS WEIGHT

Weight is an important factor to some patients, as is the availability of joint motion of the orthotic system. Plastic, because of its potential to be lighter than metal, is sometimes preferable. For the patient with weak hip flexors, efforts to minimize weight are warranted since any extra weight at the end of the limb will make it more difficult to lift the foot and advance the leg. Lehneis, et al.[8] found that improving orthotic stability at the ankle reduces energy costs. It follows, then, that in any orthotic design, stability (control about a joint) should not be sacrificed merely to achieve lighter weight.

EXERCISE PHYSIOLOGY

It is necessary to understand several fundamental principles of exercise physiology to interpret the results of energy expenditure measurements in paraplegic patients.[1] The use of oxygen consumption is based on the fact that during sustained exercise, most of the ATP for muscle contraction is generated by aerobic metabolic pathways. After several minutes of exercising at a constant submaximal workload, the rate of oxygen consumption rises until it reaches a level sufficient to meet the metabolic demands of the exercising muscle. Measurement of the rate of oxygen consumption at this time reflects the energy cost of the activity and indicates the exercise intensity. The oxygen cost per meter walked determines the efficiency of ambulation.

The principle fuels for aerobic metabolism are carbohydrates and fats. The oxidation of glucose can be summarized by the following equation:

$$\text{GLUCOSE} + 36\ \text{ADP} + 6\ O_2 \rightarrow 6\ CO_2 + 44\ H_2O + 36\ \text{ATP}$$

During exercise, the extent to which anaerobic pathways contribute to the production of energy depends upon the intensity of the effort. In mild to moderate exercise (approximately 50 percent of the maximal aerobic capacity for untrained individuals), the oxygen supplied to the tissue for the aerobic energy producing reactions is usually sufficient to meet energy requirements. During more strenuous exercise, anaerobic oxidation processes also occurs.

The amount of energy that can be produced by anaerobic means is limited. Nineteen times more energy is produced by the aerobic oxidation than by anaerobic oxidation. Also, accumulation of lactate in muscle and blood leads to

acidosis, limiting the extent to which intense exercise can be performed. From a practical standpoint, anaerobic oxidation provides an extra supply of energy for sudden bursts of strenuous effort, but these pathways cannot be routinely utilized for a prolonged time. In contrast, when exercise is performed below anaerobic threshold, an individual can sustain exercise for many hours without exhaustion.

MAXIMAL AEROBIC CAPACITY

The maximal aerobic capacity (VO_2 max) is the single best indicator of physical work capacity and fitness. It measures the individual's maximum energy production capability. Generally, an individual is able to reach the VO_2 maximum within two to three minutes of instituting strenuous exercise. Any disorder of the respiratory-cardiovascular muscle or metabolic systems that restricts the supply of oxygen to the muscle decreases the VO_2 max. A physical conditioning program can increase aerobic capacity by several processes which include improving cardiac output, increasing the capacity of the muscle to extract oxygen from the blood, increasing the level of hemoglobin, and increasing the muscle mass. On the other hand, the maximal aerobic capacity can be reduced due to blood loss, paralysis, surgery, negative nitrogen balance, or bed rest.[1] The important clinical implication is that the paraplegic patient is usually severely deconditioned as a consequence of the injury. The prescription of orthoses and a walking program should not be initiated until the patient has sufficient strength and maximal aerobic capacity to meet the required energy demand. The deconditioned paraplegic patient will respond to a physical conditioning program just as an able bodied subject with respect to increased strength, endurance, and maximal aerobic capacity.[5]

In able bodied subjects, the VO_2 max also depends on the type of exercise. During lower limb exercise, the VO_2 max is greater than the VO_2 max for the upper limbs. Since paraplegic patients rely on the upper extremities to walk with the aid of crutches, their energy production capability is inherently limited. The problem in paraplegics is further compounded by the effects of the spinal injury. The upper extremity VO_2 max for paraplegics is lower than for able bodied subjects, presumably due to the effects of paralysis and interruption of the autonomic neurological pathways which regulate blood flow and cause venous pooling in the lower extremities.[6,11] For the typical adult male paraplegic, we establish a VO_2 max of 20 ml/kg-min during upper arm cranking as the minimal criteria acceptable for entering gait training if a swing-through crutch assisted gait pattern will be required.

ENERGY EXPENDITURE

Wheeling Versus Normal Walking

On a hard, level surface paraplegic wheelchair use is as efficient as normal walking. A comparison of the data in Figure 2 indicates that when propelling a chair around a 60.5 meter circular track, the speed was almost as fast as normal walking (72 versus 80 m/min).[10] The oxygen rate was approximately the same (11.5 versus 11.9 ml/kg/min) (Figure 3), as was the oxygen cost (.16 versus .15 ml/kg/min). The heart rate was higher in paraplegics using the wheelchair than in normal walking (123 versus 100 BPM) (Figure 4). As previously mentioned, this relates to the lower upper maximal aerobic capacity in paraplegics during arm exercise. From a clinical standpoint, it may be concluded that the wheelchair is a highly efficient means of transportation whose speed and energy requirements are comparable to that of normal walking.

Swing Through Gait

Crutch walking with a swing-through gait requires the arms and shoulder girdle to lift the entire weight of the body and swing it forward with each step. The average speed in paraplegics trained to use a swing-through crutch assisted gait was 64 percent lower than normal walking (20 versus 80 m/min) (Figure 2); the rate of oxygen consumption was 38 percent greater (16.5 versus 11.9 ml/kg/min) (Figure 3); the oxygen cost was 560 percent greater (.84 versus .15 ml/kg/min); and the heart rate was increased 46 percent (145 versus 99 BPM) (Figure 4).[10] This rate of energy expenditure requires most of the aerobic capacity of the typical adult male paraplegic with a complete T12 lesion and is well above the anaerobic

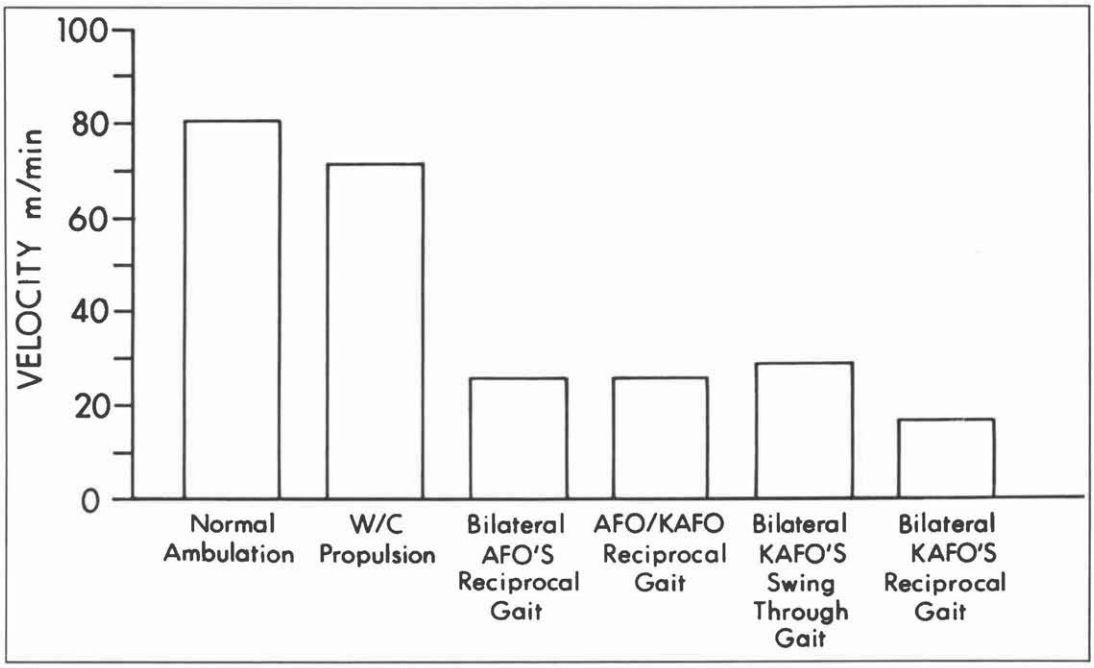

Figure 2. Average velocity in normal subjects and in patients using wheelchairs or orthoses.

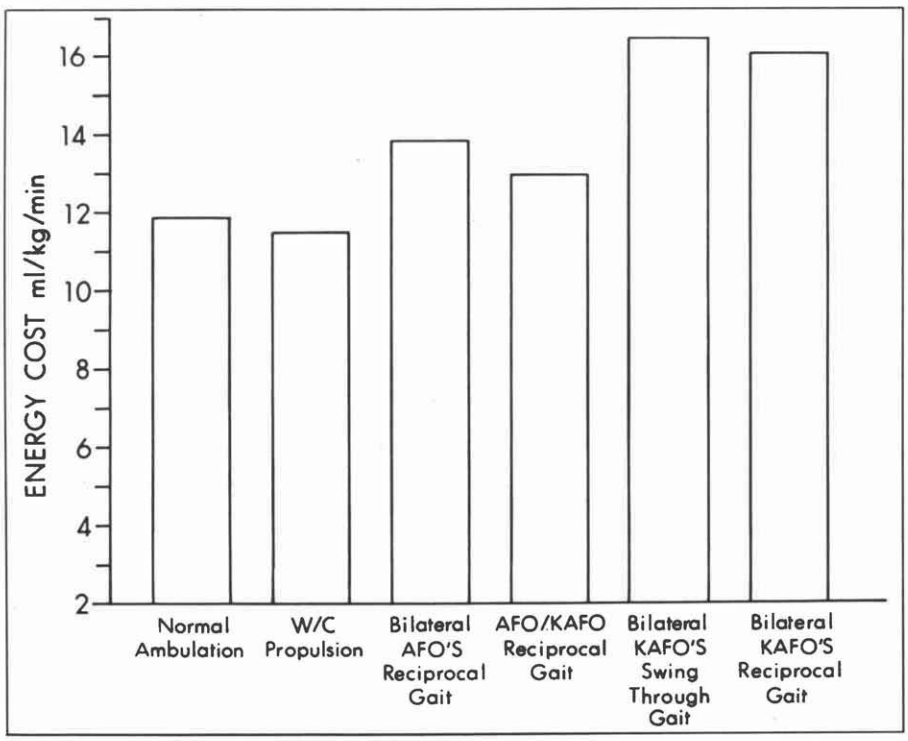

Figure 3. Rate of oxygen consumption in normal subjects and in patients using wheelchairs or orthoses.

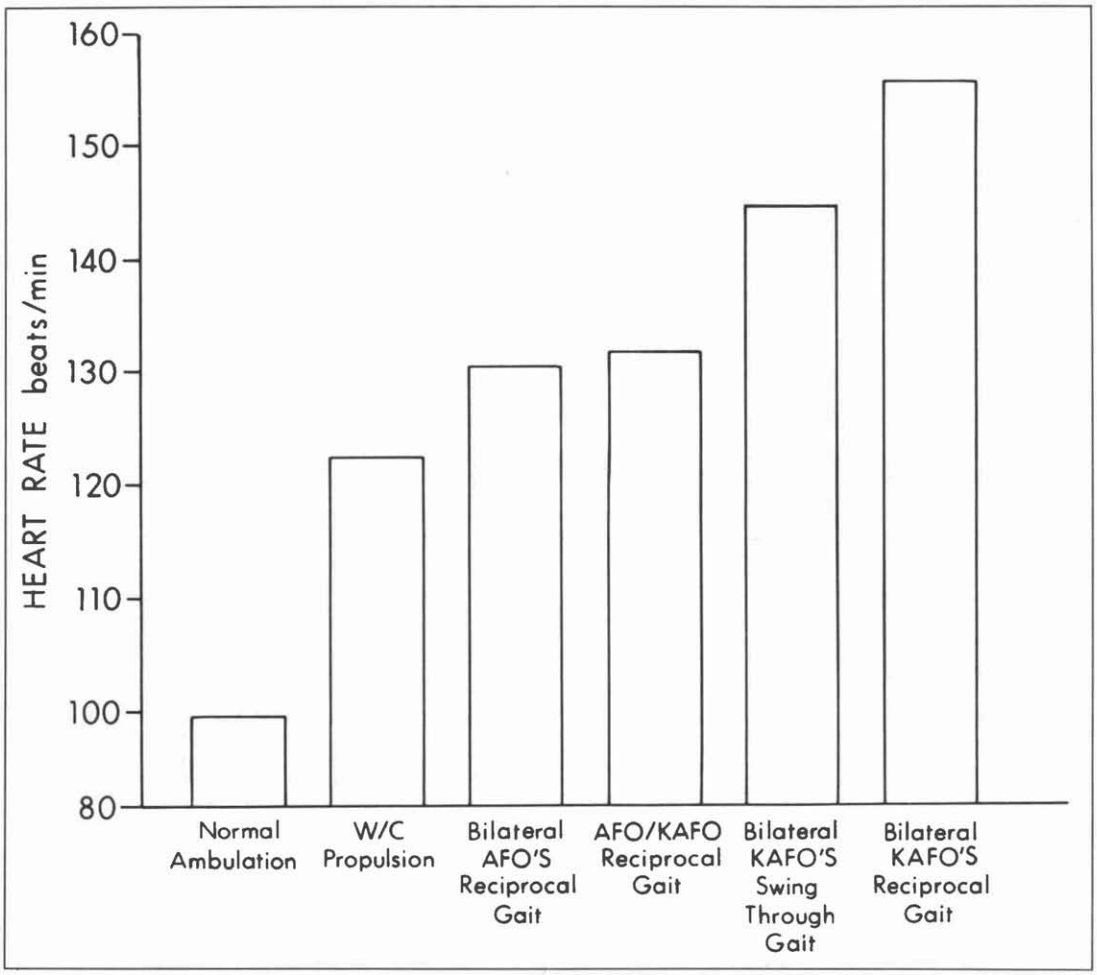

Figure 4. Heart rate in normal subjects and in patients using wheelchairs or orthoses.

threshold. The extreme exertion required for a swing-through gait demands a greater intensity of physical effort than a normal individual customarily expends on sports activity such as recreational jogging. Consequently, it is not surprising that while the athletic paraplegic may be willing to expend this level of exertion for recreational purposes, he is unwilling to sustain these efforts for normal activities of daily living. Even those patients, who are physiologically capable of sustaining the intense physical effort of a swing-through gait for a sustained time period to travel longer distances, find tachypnea (rapid breathing), tachycardia (rapid heart rate), and hidrosis (sweating), unacceptable for routine activities of daily living.

We believe that the highly motivated paraplegic who is willing to exercise strenuously should not be discouraged from walking, but a more realistic approach should be taken for the average patient. The average patient should be given walking training and bilateral knee-ankle-foot orthoses only if walking is necessary for psychological reasons, for purposes of exercise, or because of architectural barriers in the living environment. It should be clearly explained that the wheelchair should be considered as the primary means of mobility.

We have tested three patients with "Fair+" hip flexors who used bilateral KAFO's and preferred a reciprocal gait pattern.[10] Interestingly, the effort expended by these patients was just as great as in swing-through gait (Figures 2, 3, and 4).

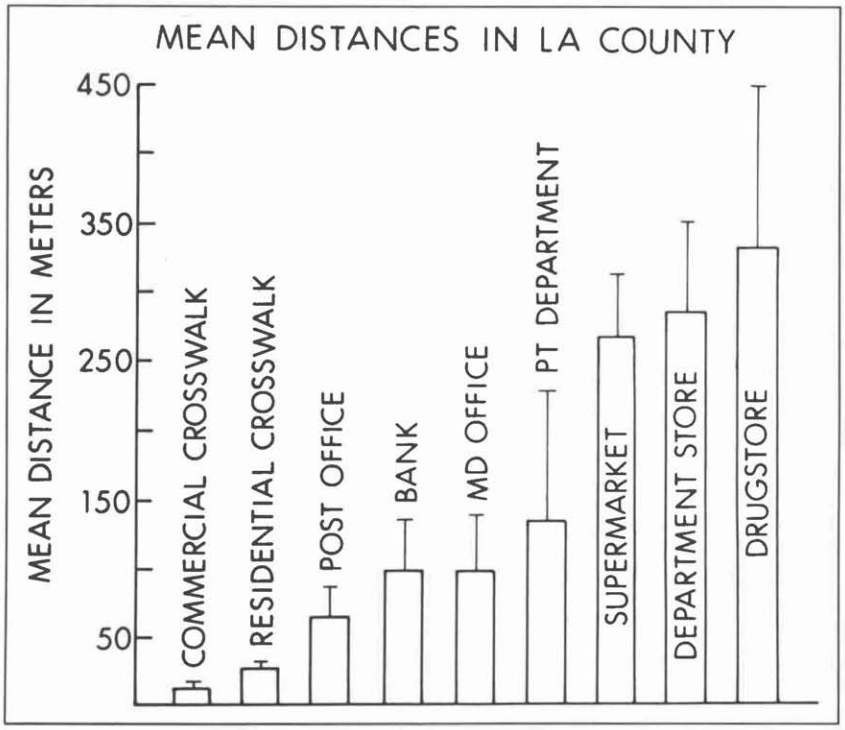

Figure 5. Average distances necessary to perform customary activities of daily living.

Energy Expenditure: Reciprocal Gait

In a review of spinal cord injured patients, Hussey and Stauffer found that those patients who were able to walk in the community had pelvic control with at least "Fair" hip flexor strength and at least "Fair" extensor strength in one knee so that a maximum of one KAFO was required, enabling the patient to achieve a reciprocal gait pattern.[6] Having "Fair+" or greater quadriceps strength sufficient to stabilize one knee eliminates the need for one KAFO and enables the patient to walk with a crutch assisted reciprocal gait pattern at a rate of energy expenditure and heart rate that are significantly below that required for a swing-through gait pattern (Figures 3 and 4). Surprisingly, we found no difference in the speed and rate of energy expenditure in patients with one free knee or two free knees and requiring bracing only below the knee (Figures 2 and 3).

Nevertheless, paraplegics who have intact hip flexion and knee extension bilaterally require orthoses only below the knees, and those who use a reciprocal crutch assisted gait pattern are still severely impaired (Figures 2, 3, and 4). Compared to normal walking, the rate of oxygen expenditure is 20 percent greater (16.3 versus 11.9 ml/kg/min) (Figure 3), the heart rate 31 percent greater (131 versus 100 BPM) (Figure 4), and the speed 67 percent slower (80 versus 20 m/min) (Figure 2).[10] The typical paraplegic who uses crutches and a reciprocal gait still exerts a force of 25 to 50 percent of total body weight on the crutches with each step, accounting for the increased rate of energy expenditure. The only spinal cord injured patients we have tested whose energy expenditure during walking does not exceed normal values are those patients with minimal involvement who have intact sacral function (in addition to lumbar function) and a sufficient hip abductor and extensor strength to maintain an erect posture without crutches.

The average distances necessary to perform different daily living activities are listed in Figure 5 and were obtained from numerous measurements made in different types of urban areas in Los Angeles.[8] Since the average speed of walking in low lumbar paraplegics who

used bilateral ankle-foot orthoses and a reciprocal crutch assisted gait pattern was only 26 m/min, it would take more than five minutes to travel 150 meters. Because five minutes of walking will require a strenuous effort, it is apparent why even the typical low lumbar paraplegic is a limited walker outside the home and is not able to routinely ambulate comfortably for activities which require walking a longer distance. In this regard, clinicians are justified in prescribing a wheelchair to any spinal injury patient who requires crutch assistance. The patients should be encouraged to use the wheelchair as necessary and be reassured that reliance on the wheelchair, when necessary, should not be considered a failure.

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Clinical Prosthetics and Orthotics, Vol. 11, No. 2, pp. 74–78

Post-polio Syndrome: An Overview

by Neil R. Cashman, M.D.
Irwin M. Siegel, M.D.
Jack P. Antel, M.D.

Poliomyelitis was a dreaded disease of developed countries, affecting tens of thousands of children and adults during each of the epidemic years up to the mid-1950s. The polio virus is a small RNA virus whose only natural host appears to be man. The vast majority of exposed persons develop either an inapparent infection or a non-specific flu-like illness (non-paralytic poliomyelitis). Secondary invasion of brain and spinal cord is associated with infection and death of motor neurons, with loss of innervation to muscle fibers, and consequent muscle weakness and atrophy. Postmortem studies show that muscle weakness in poliomyelitis is clinically apparent only when more than half of corresponding motor neurons are destroyed.[1] Frequently, muscles can be reinnervated by healthy neighboring motor neurons by a process of axonal sprouting. Thus, partial or complete recovery of muscle bulk and strength can occur, in which subnormal numbers of motor neurons support increased (up to 8-fold) numbers of muscle fibers.[2] It is estimated that about 250,000 people in the United States have survived paralytic poliomyelitis and are alive today.[3]

Recently, it has become clear that some patients who had paralytic poliomyelitis may develop new complaints after decades of stable function.[3–11] These new symptoms have been designated the "post-polio syndrome" (PPS) or "late sequella of poliomyelitis." Although some reports of new weakness following polio can be found in the medical literature since 1875,[5] recent epidemiologic studies indicate that new symptoms are common, occurring in approximately 25 percent of patients with antecedent paralytic poliomyelitis.[4] If this estimate is correct, over 50,000 persons in the U.S. are at risk of developing PPS. From published reports, the mean latency of onset has been calculated to be 36 years.[5] Thus, an increasing incidence of new cases will probably continue into the early 1990s, reflecting the last epidemics of the mid-1950s.

The risk of developing PPS appears to correlate with severity of the original poliomyelitis. Thus, a patient with four-limb involvement and a history of respiratory dependence during his polio is more likely to develop new symptoms than a patient with one-limb involvement.[6] The severity of the original onset of polio also seems to predict the latency of developing the syndrome; severely affected patients may develop new symptoms after only 10–20 years, whereas mildly affected patients are more likely to exhibit extended delays in time of onset of PPS.[6]

What causes PPS? Why should a patient who has had stable function for decades develop new symptoms? At the present time, there is little definitive data on this subject. Early conjecture focused on a possible reactivation of the polio virus which had remained latent in the nervous system since the original infection. However, there appears to be little or no evidence for inflammation in post-polio patients; spinal fluid is without the cells, protein, and immunoglobulin which characterize other nervous system viral infections. Some investigators have suggested that the normal attrition of neurons with aging may trigger the post-polio syndrome when superimposed on previous static damage of polio.[7] However, aging-related loss of neurons in the spinal cord normally begins about age 60[12]; the onset of PPS most commonly occurs 30 years after polio and does not correlate with chronological age of the

The University of Chicago Post-Polio Clinic: Presenting Complaints in 97 Patients

Symptom	Number	Percent
Pain	75	77.3%
Fatigue	60	61.8%
New Weakness	54	55.6%
New Atrophy	15	15.4%
Pain, Fatigue, Weakness	32	33.0%

Table 1.

patient.[7] Weichers and Hubbel[8] and Dalakis, et al.[9] have suggested that motor units grossly enlarged by reinnervation in recovery from poliomyelitis may begin to experience peripheral disintegration with the passage of time. Our own data support this hypothesis in part; late denervation is most common in muscles with the greatest degree of reinnervation. However, we find that group atrophy, a putative indicator of motor neuronal disease (and not terminal axonal degeneration), is also common in patients with prior poliomyelitis.[10]

Although a bewildering variety of new symptoms are recognized as occurring in PPS,[4] most new complaints appear to be subsumed under the three major problems of new pain, new weakness, and fatigue (Table 1). Some investigators have theorized that new muscle atrophy and weakness constitutes a separate syndrome, ''postpoliomyelitis progressive muscular atrophy'' or PPMA.[9] In this scheme, other symptoms of PPS, such as pain and fatigue, are thought to be manifestations of a separate ''musculoskeletal'' syndrome due to chronic strain of muscles and joints that have been forced to bear weight in an unnatural fashion.[11] Common orthopedic deformities in patients with poliomyelitis include knee valgus, varus, and recurvatum, as well as ankle equinus.[13] However, new weakness can result in new joint instability, and new joint problems may interfere with efficiency of movement. Although a symptomatic approach to separate complaints of PPS patients is warranted, there is little scientific data which supports a division of sub-syndromes of PPS at present. We have found that even patients without new symptoms have evidence of an ongoing neuromuscular disorder.[10]

New pain is the most common symptom in PPS based on our experience (Table 1), and is a frequent complaint in other series as well.[4,6] We have evaluated patients experiencing pain in conjunction with an orthopod experienced in neuromuscular disease. Several causes of pain are commonly identified in PPS patients. Perhaps the most common cause is insertional tendonitis and/or bursitis from chronic overuse and strain of muscle groups with subnormal strength. Palpation of tendons and bursae at common sites of involvement, such as the pes tendon at the medial knee and the trochanteric bursa, will often reveal profound point tenderness consistent with this syndrome. A trial of rest and non-steroidal anti-inflammatory agents may induce remission in this remitting/relapsing syndrome. For certain local sites, a steroid injection may be useful; weight reduction and readjustment of weight-bearing (through retraining and/or orthotic devices) may also produce long-range benefits. Degenerative arthritis, found most often in weight-bearing joints (where walking aids are used, the joints of the upper extremities may indeed become weight bearing), may also respond to the same regimen. Nerve compression syndromes characterized by pain and paraesthesias, secondary to positional or repetitive stress, should also be considered in the differential diagnosis of pain in PPS patients.

Another type of pain, unrelated to joint ''wear and tear'' is muscle pain. This occurs frequently during or after exercise, and may be associated with cramps, fasciculations, or intense local fatigability. This may be related to muscle substitution and/or overwork in denervated muscle, and may ultimately be associated with permanently increased weakness.[14] Treatment of this muscle pain includes avoiding the circumstances which induce it. Rest, orthoses, or even intermittent wheelchair use should also be considered to reduce load on overworked muscle. Medications which reduce muscle cramps (quinine, diphenylhydantoin) may increase weakness, and should be avoided.

Fatigue is also a common complaint in PPS patients, occurring in over 60 percent of our series (Table 1). Two types of fatigue are reported by patients: generalized fatigue re-

quiring rest or sleep, and local muscle fatigue. Local muscle fatigue is most common in muscles previously severely affected by polio, and is often associated with cramps and fasciculations. Local fatigue may be a manifestation of ongoing muscle denervation, and is also reported by patients with classic denervating diseases such as amyotrophic lateral sclerosis.[15]

Generalized (systemic) fatigue is common in PPS, but may also be a symptom of a variety of other states, including medical conditions such as diabetes mellitus, cardiopulmonary dysfunction, and thyroid disease. Depression (''low energy'') may also lead to systemic fatigue. Once medical and psychiatric diseases have been ruled out, systemic fatigue in PPS may be a symptom of widespread neuromuscular junction transmission defects. We have found that patients with fatigue and marked increased jitter in single-fiber electromyography (an indicator of defective neuromuscular transmission) respond to agents which enhance neuromuscular transmission, such as the anticholinesterase pyridostigmine (Mestinon). Rest, ambulatory aids, and activity planning may also alleviate generalized fatigue.

New weakness is the third major component of the ''post-polio triad'' (Table 1). When new weakness occurs with new muscle atrophy, PPS patients are thought by some investigators to suffer from a specific syndrome of post-poliomyelitis progressive muscular atrophy (PPMA).[9] It has been suggested that that evidence of ongoing denervation (fibrillations and positive waves on EMG, increased jitter on single-fiber EMG, and atrophic muscle fibers on muscle biopsy) are diagnostic for this syndrome.[9] However, we have found that electrophysiologic and muscle biopsy evidence of denervation is as common in polio patients who are not having new symptoms, as in patients who have clinically defined PPMA.[10] Moreover, evidence of denervation is most severe in muscles which show the most signs of old polio.[10] Thus, late denervation appears to be a concomitant of massive monophasic antecedent denervation, and not a sign of new disease. In addition, we found that although 14 out of 15 patients who complained of new atrophy also reported new weakness, only about one-half of patients who reported new weakness noted new atrophy.[5] Thus, the relationship of atrophy to weakness is not clear.

New muscle weakness may put extra stress on a previously borderline compensated muscle, producing pain, cramping, and an ''overwork myopathy,'' with accelerated weakness as an end result.[14] It has been estimated that a partially denervated muscle graded ''good'' must work two and a half times as hard as normal muscle to accomplish the same task.[1] We caution patients with new weakness to reduce activity. Exercise programs must be undertaken with extreme caution, and exercise should never be performed to the point of pain or muscle cramps. We advice patients to exercise limbs not previously affected by polio or, if this is impossible, participate in a carefully graded program in a therapeutically heated pool. One should exercise enough to prevent atrophy of disuse, but not enough to cause damage from overuse. High repetition, low resistance exercises are favored, as well as stretching and isometric drills. Orthotic devices, including the ankle-foot orthosis and knee-ankle-foot orthosis, may provide support for certain critically weakened muscle groups, although adequate function of other muscle groups (e.g., knee and hip extensor function for an ankle-foot orthosis) is a prerequisite for effective use. Wheelchair use should also be considered, sometimes only intermittently, as prolonged activity may predispose the patient to osteoporosis or venous thrombosis. Training in effective transfers, efficient movements, etc. by the physical and occupational therapist may also be useful, as can home help aids such as a shower chair and raised toilet seat.

Limb weakness may result in new joint instability, which in turn may be associated with new pain and increasing deformity. It has been noted, for example, that floor reaction with knee hyperextension serves a knee-locking function when the quadriceps is weak.[16] However, profound degrees of weakness can provide a ''positive feedback'' situation where posterior knee ligaments are subjected to more torque stress, leading to further stretching.[16] A knee-ankle-foot orthosis (fit with a posterior offset knee hinge) may prevent progressive joint damage in this situation.

Pulmonary complaints may occur in patients with previously weakened diaphragm, intercostals, abdominal, or accessory muscles. Frequently, a patient with previous paralytic poliomyelitis, involving muscles of respiration, will

have borderline respiratory compensation for decades, and will undergo precipitous respiratory failure later in life.[17] Increasing scoliosis, aspiration pneumonia, gradual loss of motor units with aging, and other factors may contribute to respiratory insufficiency. Respiratory symptoms (daytime somnolence, snoring, dyspnea, etc.) must be sought in all patients, particularly those with a history of respiratory involvement with polio. Baseline spirometry is also obtained in patients attending clinics. Muscle relaxants and medications which suppress respiratory drive should be avoided. Vaccines (pneumonia and flu vaccines) and cessation of smoking are also important in patient management. New respiratory muscle weakness may also present as sleep apnea, which may respond to medication (e.g., protriptyline), or may require night time oxygen or mechanical ventilation. Pulmonary complaints should always be evaluated and treated in conjunction with a pulmonary physician versed in neuromuscular diseases.

Prognosis of the post-polio syndrome depends upon the symptoms experienced by the patient and upon individual (as yet uncharacterized) differences in disease progression. General health care measures (proper rest, nutrition, weight management, etc.) as well as psychosocial support are important. Inflammation in joints and muscles may be managed well with the treatments cited above. At least some patients with PPS fatigue respond to anticholinesterase medications. Progressive weakness, with or without atrophy, is the least responsive symptom of PPS. Respiratory complaints, particularly, should be considered seriously. Fortunately, weakness progresses slowly (about one percent per year according to a recent study),[9] and plateaus in function are observed. Although rapid progression of weakness does occur in some PPS patients, other diagnoses such as medical illnesses or superimposed neurologic and orthopedic problems must be considered.

A common complaint of post-polio patients is that health professionals do not understand or even believe their new symptoms. Although a breakthrough of understanding on PPS may not occur in the immediate future, it is the responsibility of all health personnel to listen carefully to patients with new problems and provide the best care possible. Specific symptomatic treatment should be made available where appropriate. The patient who has rehabilitated from the effects of acute polio must now be helped to accept the activity aids and lifestyle modifications necessary to ameliorate his "second disability."

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Clinical Prosthetics and Orthotics, Vol. 11, No. 2, pp. 79–81

A New Look at the RGO Protocol

by Lou Ekus, C.P.O.
Linda McHugh, R.P.T.

INTRODUCTION

The L.S.U. Reciprocal Gait Orthosis (RGO) is an orthotic device that gives structural stability to the patient with lower trunk and lower limb paralysis while allowing, through a cable coupling system, reciprocal hip joint motion for ambulation. The device has been used at the Shriners Hospital in Springfield, Massachusetts since December, 1980. Our experience with the Reciprocal Gait Orthosis has led us to a simplified approach in the selection, fitting, and training of patients suitable for fitting with this device.

PATIENT DISTRIBUTION

Sixteen fittings with the Reciprocal Gait Orthosis have been reviewed for this article. Seven of these children were under the age of four years at the time of their first fitting, with a total of 12 children under the age of eight at the time of first fitting. All 12 children were discharged from the hospital using the orthosis effectively. One child in this group later rejected the orthosis because he was able to ambulate with bilateral knee-ankle-foot orthoses and felt the Reciprocal Gait Orthosis was too much bracing. Out of this group, the remaining 11 children are currently community ambulators and wear the orthosis for most of the day.

In addition to these 12 children, we have four young adults who are fit with the Reciprocal Gait Orthosis. Three of them were 13 years old at the initial fitting. Two of these children were discharged from the hospital using the orthosis effectively and are currently household ambulators. The last of the 13 year olds rejected the brace due to an extreme fear of the upright position. Our last fitting was done on a 21 year old male with severe hip and knee flexion contractures. This patient had a tremendous desire to ambulate and so the fitting was attempted. However, after numerous fittings and adjustments, the attempt was abandoned as a result of the severity of his contractures.

PROTOCOL

Our first patient was fit with a reciprocator in December, 1980. Subsequently, 12 children were fit following the general guidelines established by Louisiana State University. In November, 1985, we developed our own written protocol. The protocol was extremely specific, outlining prerequisites before fitting with the Reciprocal Gait Orthosis. The protocol included such criteria as, 1) hip and knees free of flexion contractures greater than 20 degrees, 2) patient required to demonstrate independent mobility in a parapodium, and 3) parents required to admit children for training.

After a review of our series up to that point, we realized that few of the patients actually met 100 percent of the criteria in our existing protocol, and yet our success rate was quite high. After a further review of the fittings was done, a revised protocol was written and instituted in June, 1986. Our new protocol for fitting with the Reciprocal Gait Orthosis is outlined below:

1) Parents and child will watch a video prepared by the hospital showing the fitting and training process for the Reciprocal Gait Orthosis.
2) A team meeting will be held prior to admission with parents and child, physical therapist, orthotist, nurse, social service representative, and physician. At this meeting, goals are set for admission and parents are given the opportunity to ask

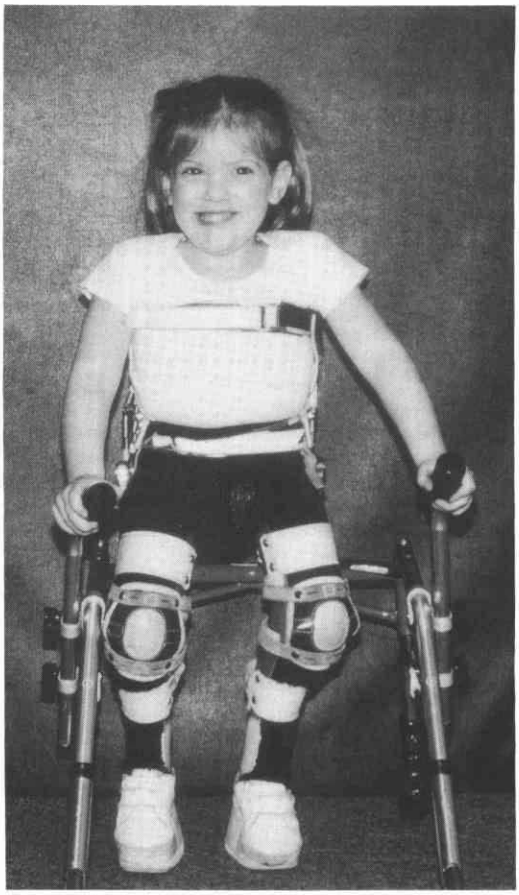

Figure 1. Front view of patient showing extensive pre-existing contractures and shoe wedging to accommodate the contractures.

any member of the team questions that they might have. The child's abilities will be discussed, including a) ability to stand and move in the parapodium, b) emotional and cognitive ability to tolerate training, c) upper extremity strength, and d) any existing joint contractures and their influence on fitting and training.

3) Goals will be set, regarding a) cooperation for training, b) balance and confidence with movement, c) quality of mobility, d) independency in transfers, and e) donning and doffing of the orthosis.

Following fitting and dynamic alignment of the Reciprocal Gait Orthosis, gait training begins. It includes 1) momentary standing balance, 2) training on the parallel bars (patient instructed to "shift weight" and "push back"), 3) progression to a rollator walker when consistent orthotic control, good balance, and even stride length are demonstrated in parallel bars, and 4) progression to Loftstrand crutches when improved independence in balance is achieved and the patient is cognitively able to use them.

Figure 2. Lateral view.

Three weeks into training, a second team meeting is held. Each goal is addressed and the team determines the best way to continue training based on the reassessed goals.

At discharge, the patient will 1) ambulate with the walker, 2) exhibit consistent control in step length, balance and stability, 3) exhibit good standing balance, and 4) be able to negotiate a ramp.

FITTING PROBLEMS

Without a doubt, the most consistent problem we've seen in fitting the Reciprocal Gait Orthosis is existing hip, knee, and ankle contractures. We have fit patients with significant contractures of these joints and have accommodated for the contractures in alignment by wedging the shoes (Figures 1 and 2). Our intention is to enable the child to exhibit effec-

tive ambulation and then to consider joint releases when possible.

We have seen, in a few cases, where it is difficult for the patient to comprehend that pushing back will advance the leg. To make this concept more easily understood in the early stages of training, the hip joints are flexed slightly more than usual to allow the patient to grasp this concept easily. This usually makes standing balance impossible. However, after a day or two, the orthosis can be extended and standing balance can be addressed. We found this to be an extremely useful tool in expediting the initial stages of training.

EARLY INTERVENTION

Taking into consideration the importance of upper limb strength, preservation of range of motion, and weight control before fitting a patient with the reciprocating orthosis, it is easy to see the importance of early intervention in cases of congenital deficiency. Through our myelodysplasia clinic, we are able to follow the patients on an ongoing basis from birth to insure continuing follow up in these areas. It is also possible to insure the delivery of an infant stander at the appropriate time. The clinic also gives us the opportunity to observe the child in the stander or parapodium. Mobility in these devices is a good indication of motivation, balance, and the child's awareness of his body moving through space. The myelodysplasia clinic gives us an invaluable opportunity to insure that all of the prerequisites are being nurtured and that we can initiate a fitting with the Reciprocating Gait Orthosis at the appropriate time.

RESULTS

Included in our series of 16 patients are 12 children who are community ambulators. In addition, two children are ambulatory in their household or for short distances, and two rejected the Reciprocal Gait Orthosis as their means of mobility. The age of initial fitting for these children spanned two years to 21 years, with children under the age of eight all being community ambulators.

CONCLUSION

Clearly, the results demonstrate the importance of both early intervention and early fitting with the Reciprocal Gait Orthosis. We hope that children with congenital paraplegia who initiate ambulation with a Reciprocal Gait Orthosis at an early age will continue to be ambulatory further into adult life than those who have used knee-ankle-foot orthoses in the past. In conclusion, we would like to propose the idea that, based on experience with our protocol, the fitting and training of a child using the Reciprocal Gait Orthosis is no more difficult than other bracing modalities and can be approached with the same ease.

AUTHORS

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Wheelchairs for Paraplegic Patients

by A. Bennett Wilson, Jr.

The best current estimates of the incidence and prevalence of spinal cord injury in the U.S. is 30–32 and 900 cases per million of population respectively.[5] About half of these cases are paraplegic. Added to this are paraplegics due to spina bifida, a few polio cases, etc. By definition, paraplegics have to rely on one or more assistive devices if mobility is to be achieved.

Only a small segment of the paraplegic population make use of lower-limb orthoses, and even those who do have orthoses, and use them, need a wheelchair as well, in order to make the most of their available energy. For the very few who can "walk" enough not to feel the need for a wheelchair in work and activities of daily living, wheelchairs permit participation in athletic activities that would otherwise be impossible.

Wheelchairs can be classified as either "manual" or "powered". The manual wheelchair is designed to be propelled by the occupant or by an attendant. Tests have shown that the energy cost of using a manual wheelchair for mobility on a smooth, level surface can be appreciably less than that of unimpaired persons walking on the same type of surface.[4] The conditions, of course, are reversed when uneven surfaces or ascending surfaces are encountered. The "powered" wheelchair is designed to be propelled by a battery-powered electric motor or motors. Originally conceived to be used by patients unable to propel themselves, powered chairs are sometimes indicated so that a paraplegic can make more effective use of his own energy.

The basic manual wheelchair has two sideframes connected by a cross-bar that is pivoted about its intersection and a flexible seat and back to allow folding, two large driving wheels at the rear, and two caster wheels at the front (Figure 1).[6] This is a configuration that has evolved over the years since the original patented design of Everest and Jennings[2] in 1936 for the folding mechanism, and represents a rather elegant compromise between maneuverability, stability, and portability. Many concerted attempts, especially in recent years, to develop better designs have not been very successful. The use of new materials has made it possible to produce significantly lighter wheelchairs, but the original configuration is basically the same.

It must be remembered that a change in the design to emphasize one feature generally affects adversely one or more of the other features. An example is when the wheelbase of the basic chair is lengthened to provide more stability for the bilateral leg amputee; maneuverability is sacrificed. Designers of some of the "sports" chairs, in order to reduce weight, have eliminated the folding mechanism. Portability is achieved by connecting and disconnecting driving wheels for transport in an automobile.

PRESCRIPTION CONSIDERATIONS

Variations of the basic chair are available for amputees, hemiplegics, and others, but the basic chair of proper dimensions is generally the most suitable for paraplegic patients. The range of dimensions of the basic wheelchairs available in the United States are shown in Figure 2.

Even when sensation is present, the hammock type seat is seldom used without cushions, which are needed to provide a better distribution of pressure over the thighs and buttocks for comfort, if for no other reason.

Cushions and other seating systems affect the relationship between the user and the chair and, therefore, must be selected and taken into ac-

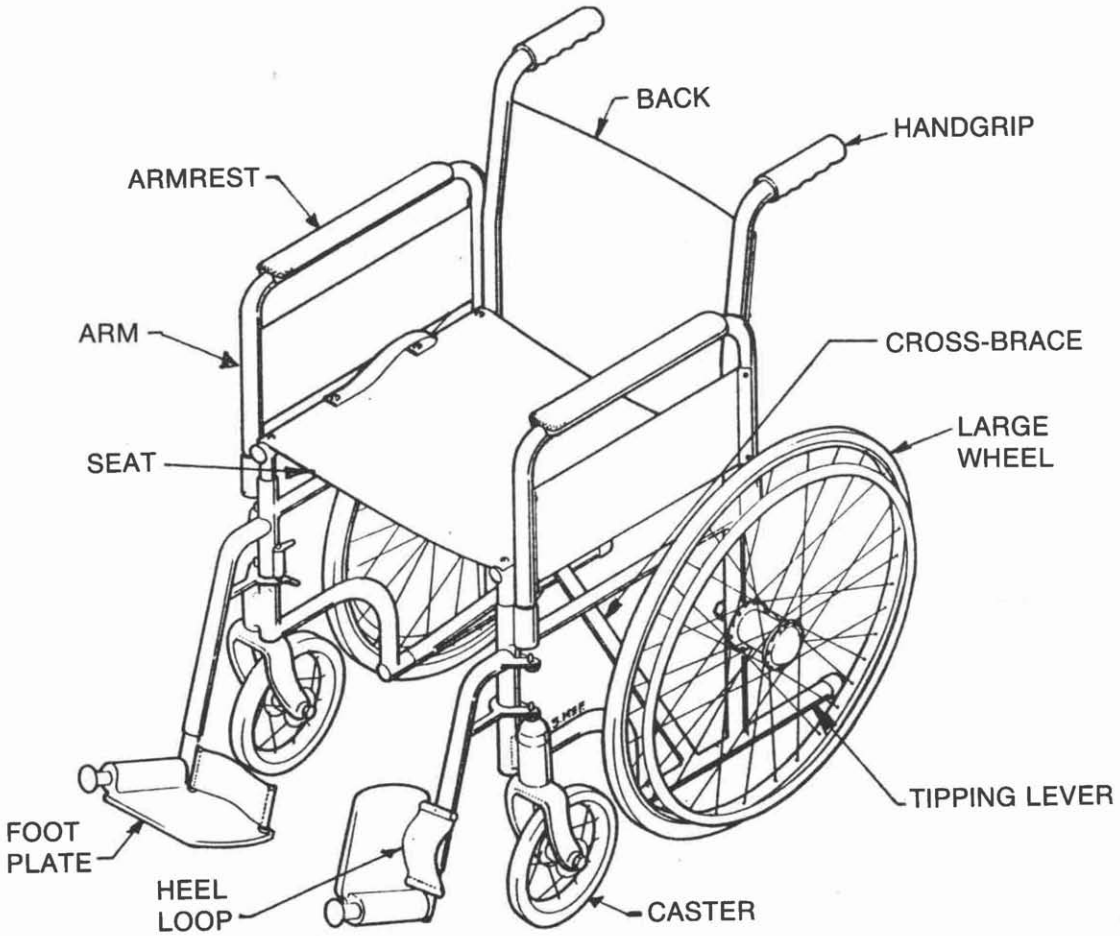

Figure 1. The basic wheelchair—folding frame, 24-inch diameter wheels in the rear, 8-inch diameter casters in the front, flexible seat and back.

count before the final dimensions of the chair are determined.

The importance of selecting the most appropriate chair and seat cushion cannot be over emphasized. The dimensions of the chair must distribute the forces of the body properly while also placing the user in a position, with respect to the driving wheels, to provide maximum efficiency during propulsion.

SEAT WIDTH AND DEPTH

Selection of the proper seat width is important to comfort and stability. A seat that is too narrow is not only uncomfortable, but access to the chair is made difficult. Furthermore, the chances of pressure sores developing is increased. A seat that is too wide encourages the user to lean toward one side, thus promoting scoliosis and increased pressure over the buttocks on one side. In addition, a seat wider than is necessary makes propulsion more difficult.

A seat that is too shallow reduces the area in contact with the buttocks and thighs and causes more pressure on the soft tissues in contact with the seat than is necessary or safe. Furthermore, the location of the footrests is changed so that the feet and legs are not supported properly, and the balance of the user can be affected.

A seat that is too long can restrict circulation in the legs.

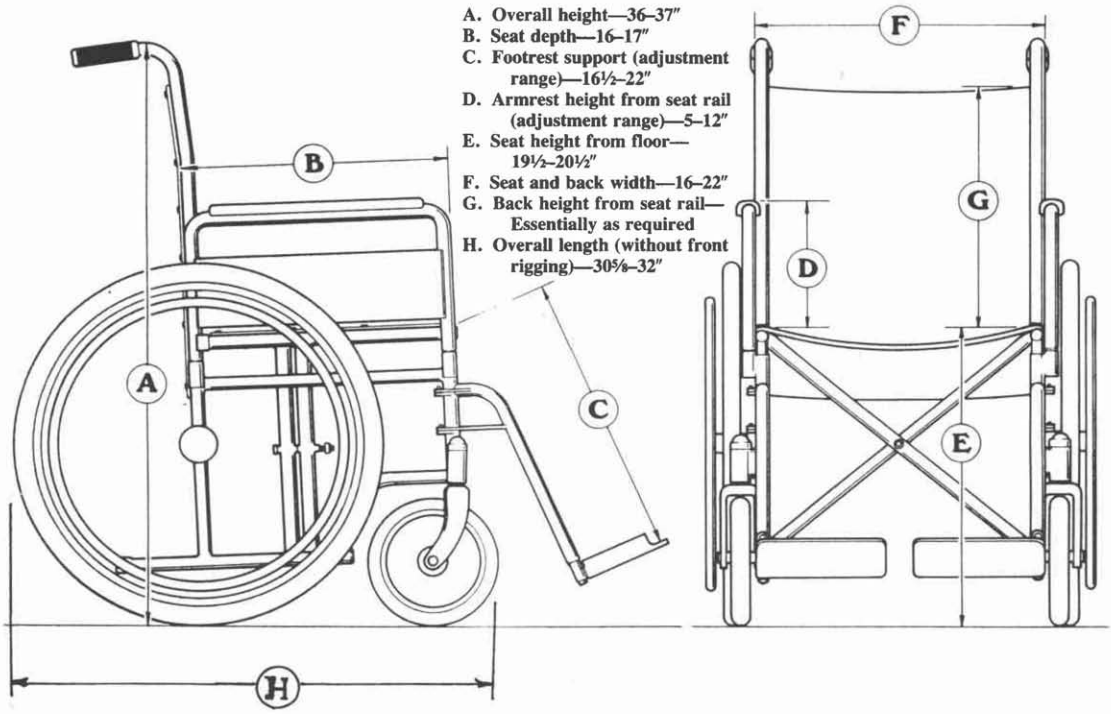

Figure 2. Dimension ranges for the basic adult wheelchairs from major U.S. manufacturers.

SEAT HEIGHT

The height of the seat above the ground of the basic adult chair is 19½–20½ inches. Tall persons require a seat that is higher and deeper; short persons require a seat that is lower. Usually these requirements can be met by a stock chair; if not, properly dimensioned units can be had on special order. Obviously, the cushion or seating system to be used will affect the end result.

SEAT TYPE

Seats available from wheelchair manufacturers are sling or hammock types, made of a flexible material, and solid seats which are generally removable (Figure 3).

The sling seats are, by far, the type most used. A solid seat installed to permit folding is available, or a removable solid wooden seat may be purchased or made.

BACKREST

The backrest of the basic chair is made of a flexible material stretched between the two side

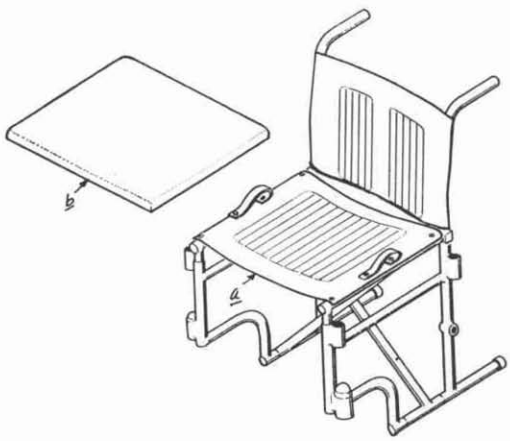

Figure 3. Seat types—a. hammock or sling; b. solid.

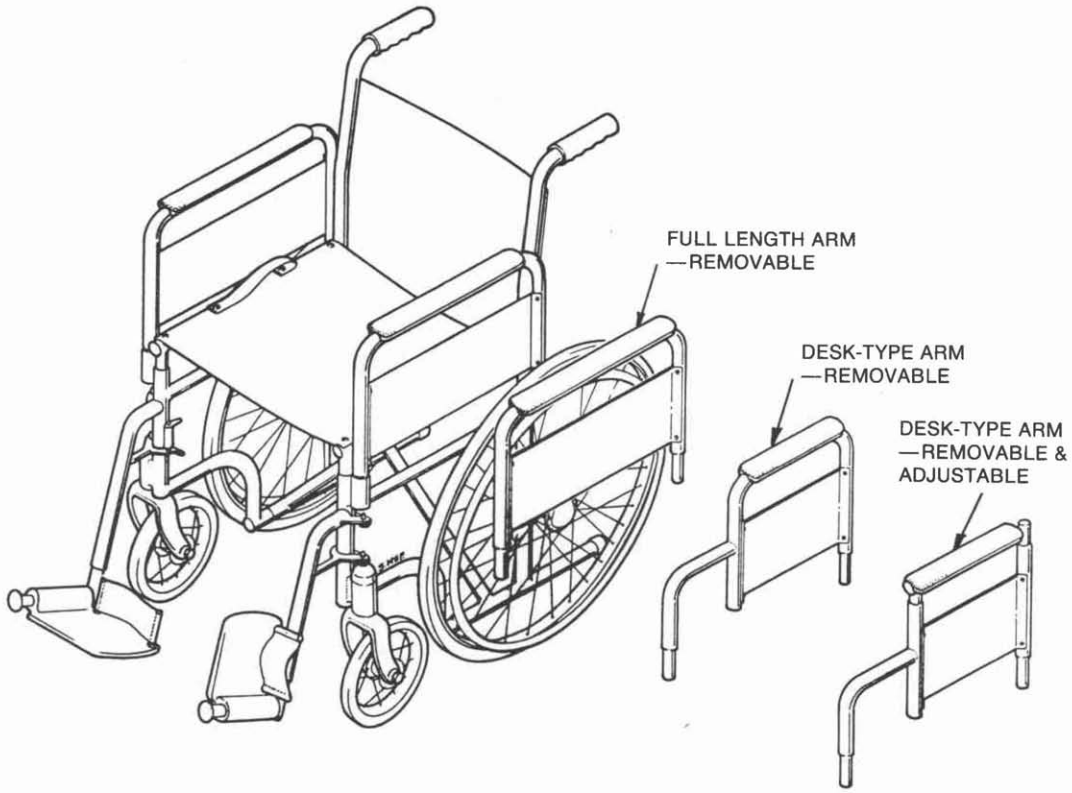

Figure 4. The basic wheelchair with the most popular types of arms—removable full-length, removable desk-type, and removable, adjustable desk-type.

frames which are fixed with respect to the seat. The backrest should be high enough to provide support without inhibiting motion, yet not so low that the scapulae can hang over the back of the chair and cause discomfort.

ARMS (Figure 4)

The lightest chairs have fixed arms or none at all. But an overriding factor in wheelchair prescription is transfer into and from the wheelchair, especially when the patient is unable to stand for a brief period. For this reason, most patients require chairs with arms that can be removed easily.

Chair arms not only provide support for the patient's arms in a resting attitude, but also provide lateral support and a reaction point for the hands when the asensitive patient elevates his body at regular intervals to prevent restriction of circulation and thus pressure sores.

Both removable and fixed arms are available in full-length and desk models; both of these styles are available with the height fixed or adjustable.

The desk models are foreshortened to permit the user to get closer to a desk or table top. The removable desk arm is by far the most popular type. The full length models are indicated when the forepart is needed to support the arms of the user in rising from the chair, or when lordosis, obesity, or some other physical factor makes it necessary to use the front part of the arm for support. The standard removable desk model can be reversed to provide this feature.

WHEELS AND TIRES

The basic chair has two 24 inch diameter rear wheels and two eight inch caster wheels in the front (Figure 5).

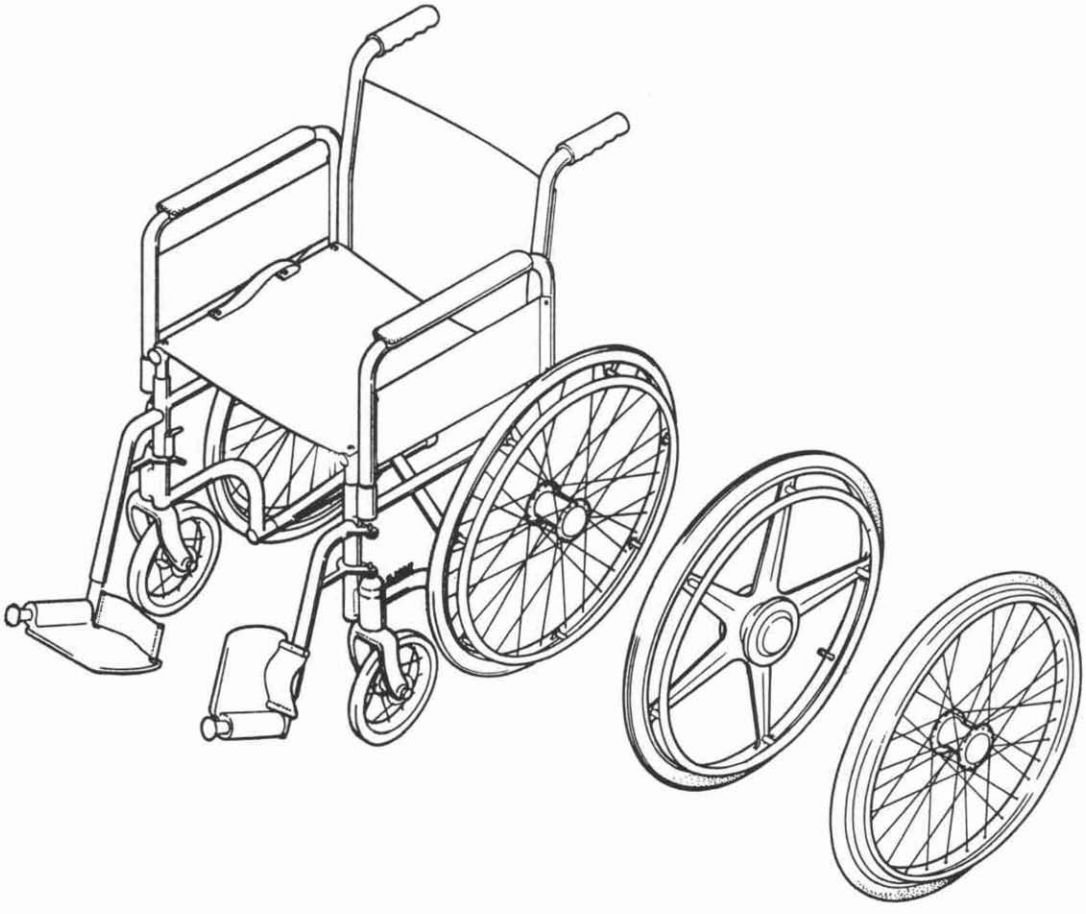

Figure 5. Basic wheelchair with standard 24-inch diameter wire-spoke wheel and two options: the cast magnesium wheel and a wheel with special built in hand rim.

The standard rear wheel for many years has been a wire spoke wheel, but wheels of cast metal alloy and wheels of cast plastic have been made available recently to overcome the maintenance problems inherent in the wire wheel design without adding more weight.

Three types of tires are available in several widths and tread types. Pneumatic, semi-pneumatic, and solid tires are available (Figure 6). The eight inch diameter wheel with solid rubber tires is standard on the basic chair, and is suitable for use on smooth surface and indoors. The semi-pneumatic and pneumatic tires provide shock absorption, and, thus, are more suitable for rough surfaces and outdoor use.

Pneumatic tires provide a more cushioned ride and their shock absorber action tends to prolong the life of a wheelchair when kept inflated properly.

HANDRIMS

Handrims are attached to the driving wheels of wheelchairs to permit control without soiling the hands. The standard handrim is a circular steel tube. For users who have problems gripping the smooth surface of a metal ring, vinyl coated rings and a variety of knobs and projections can be added to the ring.

CASTERS

Casters make steering possible and are available in two diameters: eight inches and five inches. The five inch model is available only with solid tires, and is used on children's chairs and in special circumstances on adult chairs and basketball chairs, when more maneuverability is desired.

PARKING LOCKS

Most users need some means of securing one or more wheels to keep the chair from rolling down inclines or to provide stability during transfer to and from the chair. Two types of parking locks are available from the large wheel (Figure 7): toggle and lever. Selection depends upon user preference.

Pin type locks are also available. These retain a caster in the trail position and are used to prevent swiveling during lateral transfer.

CUSHIONS

The vast majority of paraplegics require, and can use successfully, seat cushions that are

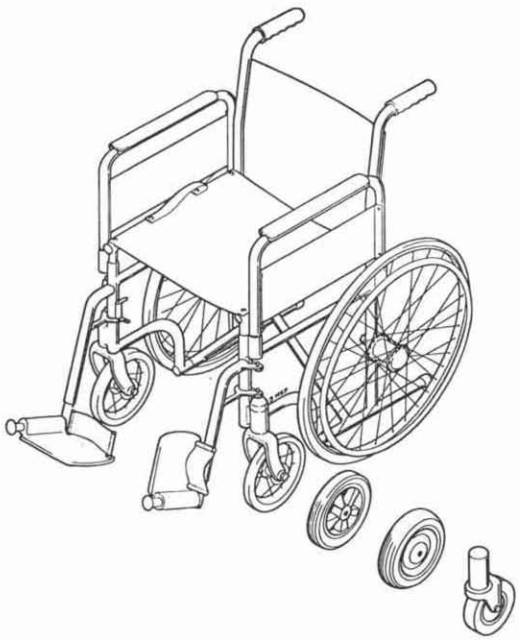

Figure 6. Basic wheelchair and optional casters available. Shown on the chair is the standard 8-inch diameter wheel with solid rubber tire. Next in order are: the 8-inch wheel with the semi-pneumatic tire; the 8-inch wheel with pneumatic tire; a 5-inch diameter wheel with solid rubber tire.

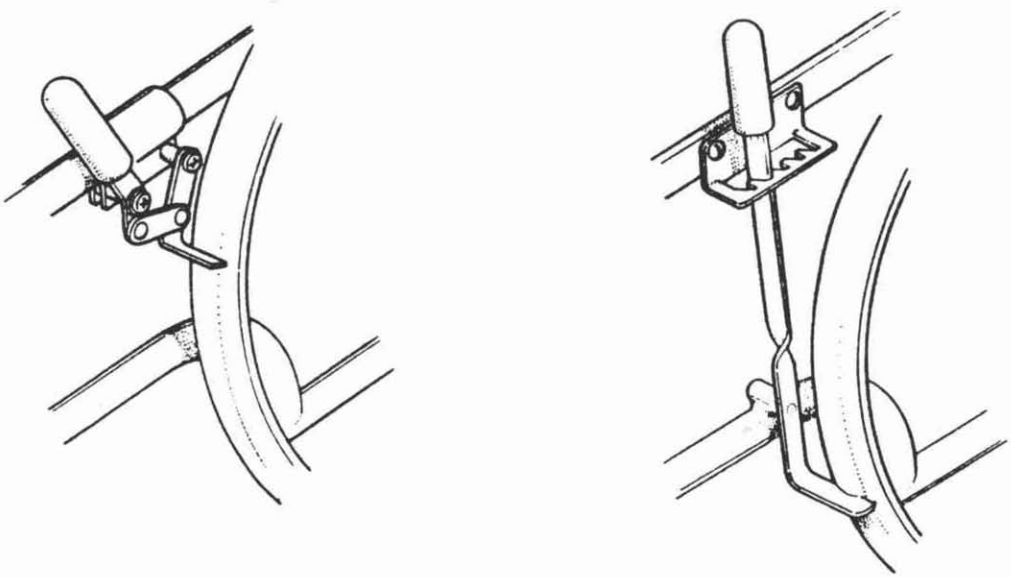

Figure 7. Two types of parking locks—left, toggle type; right, lever type. Variations of these two types of locks are available.

mass produced and are widely available at reasonable prices. A great many designs of seat cushions are available. Some have been developed by trial and error, the designs being based on what has proven to be acceptable to the inventor or his customers; other designs have a more scientific basis, but because the exact cause of decubitus ulcers is not known, precise criteria for design of wheelchair seating have not been established.[1] Although each of the cushion designs available has advantages and disadvantages, most of which are not clearly defined, selection of seat cushions for individual cases is seldom simple or straightforward.

Commercially available cushions may be divided roughly into five categories, including "miscellaneous" or "other", based on material and design (Figure 8).

1. Foam
2. Viscoelastic foam
3. Gel
4. Fluid
5. Other

Foam Cushions

Foam cushions generally use polyurethane or polyether foam, and are available in various configurations. The simplest are homogeneous rectangular blocks 2–4 inches thick; some are contoured; and others are composed of two or more layers of material of different densities, some of which may contain hollow spaces or cores in an attempt to distribute the load to specific areas.

Viscoelastic Foam Cushions

Viscoelastic foam is less resilient than ordinary foam.

Gel Cushions

Gel cushions consist of rather firm emulsion enclosed in a "non breathing" plastic casing.

Fluid Flotation Cushions

Water, air, or water-and-foam particles are used in a flexible, tailored plastic bag to provide distribution of forces. The overall effect varies with the amount of fluid introduced.

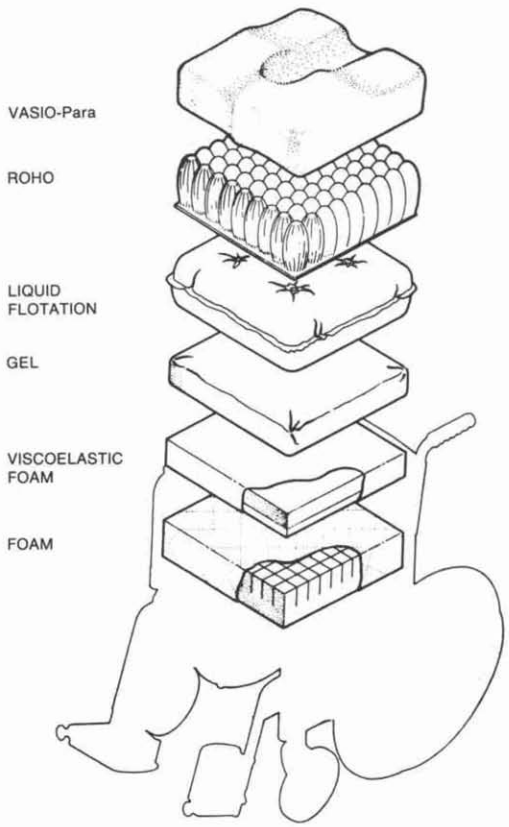

Figure 8. Various types of seat cushions that are available.

Other Types

Many other designs that combine several elements are available. Prominent among these are the ROHO, which uses a collection of air-filled tufts to distribute the loads and the VASIO (Veterans Administration Spinal Injury Orthosis), in which foams of two different densities are combined and contoured to meet the special needs of paraplegic patients.

Each type and design has advantages and disadvantages, and, therefore, selection of the type most appropriate for individual patients is not easy. Until more is known, selection has to be made on a trial basis.

SPORTS CHAIRS

Since the introduction of wheelchair basketball shortly after World War II, a constant stream of modifications and refinements has been made to the basic wheelchair to meet the needs of wheelchair athletes. Development of the lightweight, high-performance, sports chair has led to racing among wheelchair users and has made playing tennis from wheelchairs practical and enjoyable. These chairs have also been found useful in non-competitive recreation, such as camping and mountain climbing. Much that has been learned in developing and using sports chairs has resulted in improved performance and quality of prescription wheelchairs, just as automobile racing has led to improvements in the family car. At the same time, many of the people who have been using conventional wheelchairs are now using sports chairs full-time.

Like the basic prescription wheelchair, the sports chair (Figure 9) has evolved through a series of refinements to where the general configurations of most chairs are strikingly similar. At least 20 manufacturers at this time offer one or more models. Most use 24 inch diameter wheels; some use 27 inch wheels. Weight varies from 16 to 38 pounds, due mainly to material selection and whether or not the chair can be folded. A number of designs incorporate provisions for folding; Others use wheels that can be disconnected (and connected) quickly without tools to make transportation easier.

Nearly all use five inch diameter front castors, except one manufacturer that uses four inch wheels. Two make eight inch castors available as an option. Nearly all, if not all, have a feature that permits a choice of rear wheel axle position with respect to the frame (Figure 10). Only a very few offer arm rests.

Many active wheelchair users prefer to use a sports type chair all the time, and in many instances options are offered that make regular use practical. Many models have adjustable features, and most manufacturers will provide a chair with dimensions to suit a given individual.

A feature found on most sports chair, but not on other types, is the easy adjustability of wheelbase and seat height afforded by the positioning plate for the rear wheels. In many models, the position of the castor wheels can also be adjusted. Such adjustability, of course, permits the user to be seated in a position which puts the muscles in the upper limbs and

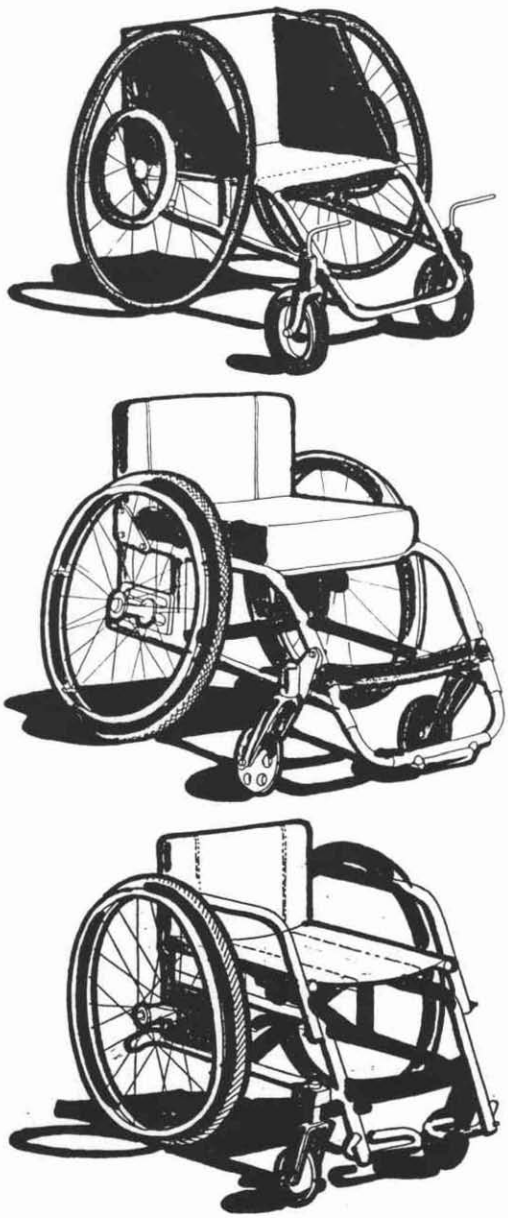

Figure 9. Three types of sports chairs. The one shown at the top is limited primarily for use in racing. The other two are more versatile.

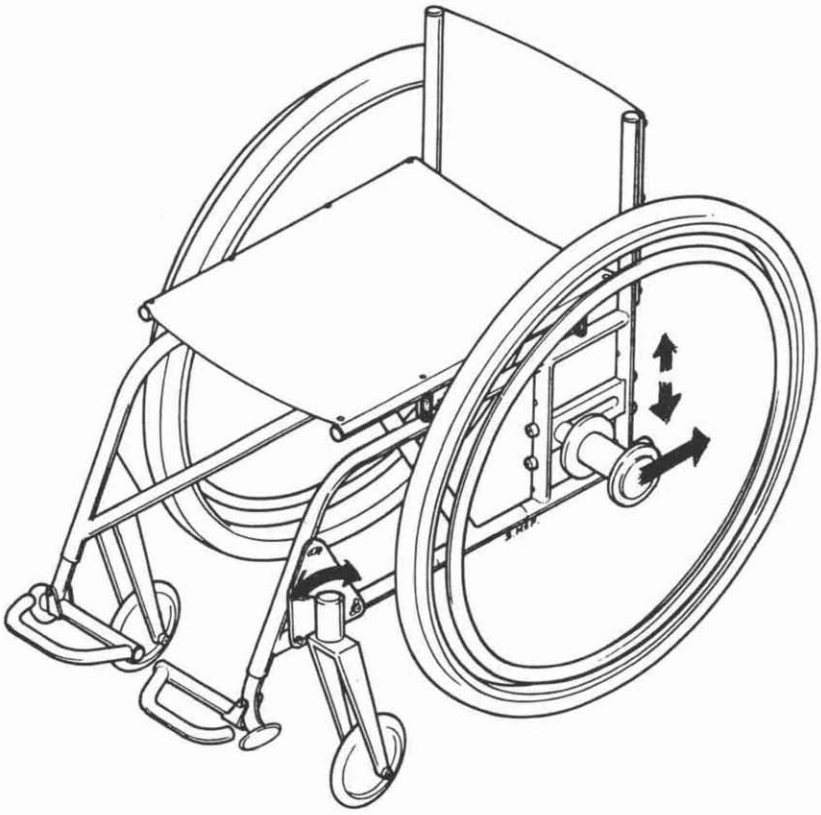

Figure 10. Schematic showing adjustability often found in sports chairs that permit an optimum relationship between position of the user and the wheels.

shoulders in the optimum arrangements for maximum biomechanical efficiency.

Because refinements and advances are being introduced so frequently, the periodical *SPORTS 'N' SPOKES*, published by the Paralyzed Veterans of America, has been devoting one issue each year to sports chairs and their specifications.[3]

SUMMARY

Because of increased competition and refinements brought about by the sports chair movement, paraplegics now have available high quality wheelchairs. No single chair design is apt to meet all the needs of each individual, but careful thought and attention to detail in prescription preparation can result in a chair that meets most of the needs of the paraplegic.

AUTHOR

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Knee Joint Materials and Components

by M.L. Stills, C.O.

The primary purpose of any orthotic knee joint, regardless of material or design, is to aid in providing stability to the patient's anatomical knee during loading of the extremity. In the paraplegic patient population, resistance to flexion of the knee is required during the periods of ground contact that occur during reciprocal gait. Orthotic knee joints can be used to provide medial-lateral control while permitting free flexion and extension, provide stance phase stability only during gait, or maintain locked knee extension during all phases of gait.

Materials used in the fabrication of knee joints for management of paraplegics are generally a hybrid of various metals, or in some cases, high-strength, reinforced composite plastics. Aluminum, and/or stainless steel machined preformed components, are common and can be considered state-of-the-art.

Mechanical knee joints are only a single component of a very complex system (Figures 1 and 2). How that component is incorporated into the entire system has an effect on the outcome of successful orthotic management. The success or failure of the entire orthotic system is dependent on many variables, i.e., accuracy of the original prescription, fabrication procedures, placement and alignment of mechanical joints relative to anatomical joints, lever arms, overall fit, training in the use of the orthosis, and the motivation of the patient.

FREE KNEE JOINTS

Free knee joints, having only hyperextension stops, are used to provide medial-lateral stability to the knee, or in situations when the patient has adequate extension power, but due to knee ligament laxity or muscle imbalance, is unable to control hyperextension.

Care must be taken when using free knee joints to check hyperextension. The orthotist must be assured that the patient has adequate voluntary muscle control to maintain knee extension. The orthosis may be required to permit a limited amount of hyperextension in order to provide stability during stance.

OFFSET KNEE JOINT

The purpose of the offset knee joint is to provide stance phase stability of the knee while permitting free knee flexion during swing phase. This should provide a more anatomical reciprocal type of gait and should reduce energy consumption.

The patient must have adequate voluntary muscle control to place the mechanical joint in a fully extended position and to move the ground reaction force anterior to the axis of rotation. The combination of ground reaction force, posteriorly offset orthotic knee joint, and a mechanical extension stop can provide stance phase stability for the paraplegic.

Many of the same factors that influence stability of the bilateral above-knee amputee also can be applied to the paraplegic patient using bilateral offset knee joints. Voluntary hip extension power is required. The use of crutches or assistive devices are almost always mandatory. Consideration must be given to the problems of uneven walking surfaces, changes in heel heights, and patient endurance. Dynamic extension assists are often added to this type joint, or an extension lock may be added and dropped into place when additional security is required.

LOCKED KNEE JOINTS

A locked knee joint (Figures 1 and 2) provides stability during the stance phase of gait and remains locked even during phases of non-ground contact. A mechanism is generally pro-

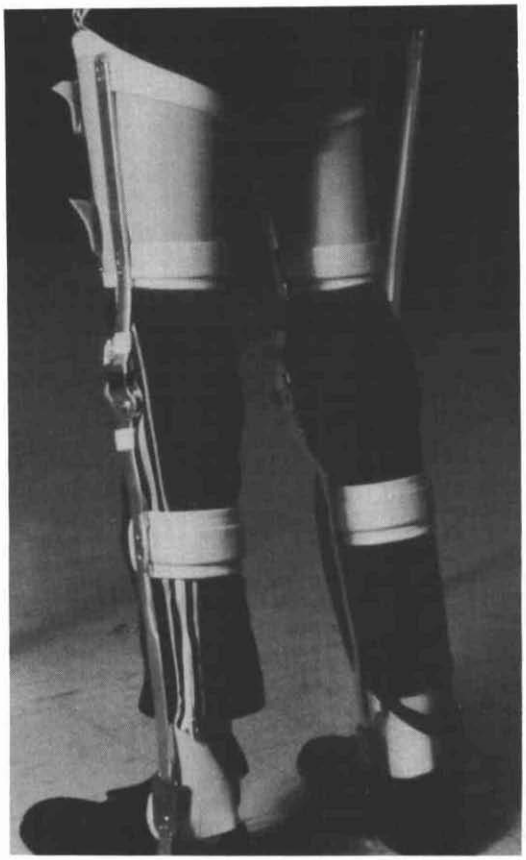

Figure 1. Conventional metal and leather bilateral knee-ankle-foot orthosis with single axis drop lock knee and double adjustable ankle joint.

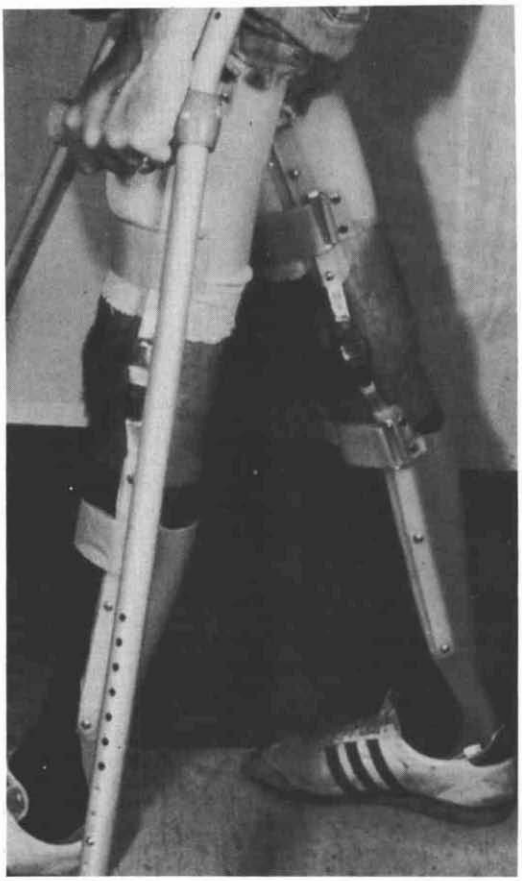

Figure 2. Bilateral polypropylene knee-ankle-foot orthosis with single axis drop lock knee and semi rigid ankle. FES was used with KAFO to facilitate swing through during gait.

vided to unlock the knee for cosmesis and comfort during sitting. Mechanisms for locking the knee joint in extension vary from simple gravity ring (drop) locks, spring-assisted drop locks, cams, pawls, and Swiss locks. Difficulty in unlocking the knee to permit sitting has led to the development of a variety of designs, again beginning with the simple ring lock, extensions added to drop locks, and bails (mechanical links between medial and lateral locks on a single extremity). To avoid accidentally unlocking a joint, designers have added ball retainers, springs, and elastic straps, all in an attempt to prevent accidental, unintentional flexion of the knee joint and subsequent falls and possible injury to the patient. There does not exist, however, a failsafe system that will completely eliminate the possibility of inadvertent knee flexion.

Solid knee orthoses have been used with limited success because of functional difficulties. Granted, the knee is stable during gait, but the inability to flex the knee during sitting makes the use of public and private transportation difficult and many times impossible. Social and public functions are difficult to manage when the user of a solid knee type device tries to sit and avoid blocking aisles or passageways. Difficulties related to a stiff knee have greatly reduced the use of surgical knee arthrodesis.

The use of medial and lateral components when fabricating knee-ankle-foot orthoses (KAFO) is commonplace. The use of such bilateral double upright construction certainly in-

creases the weight of an orthosis and requires that the fabricator use techniques that insure both medial and lateral joint surfaces are absolutely parallel and in alignment with each other.

Nitschke in 1971 reported the results of using a single lateral upright in the fabrication of KAFOs. This technique reduced the weight of the KAFO and the problem of joint alignment.

Incorporation of knee joints into a conventional metal and leather type KAFO provides the orthotist with the option of adjustability and limited skin contact (Figure 1). Incorporation of knee joints into laminated and thermoformed KAFOs (Figure 2) provides a means for more intimate fit, better control of the extremity, improved cosmesis, and lighter weight, but limited adjustability in alignment and fit of the orthosis.

The Lower Extremity Telescoping Orthosis (LETOR) (Figure 3) incorporates a new concept in knee joints. It really does not have a knee joint, but a telescoping posterior rod that, when in its extended position, bridges the anatomical knee joint and does not permit knee flexion. By lowering the telescoping rod, knee flexion is permitted during sitting. This simple telescoping bar attachment and a solid ankle system provides knee stability in ambulation and becomes a valuable training system and may be used as a definitive orthosis for the limited household ambulator.

Other methods of controlling the knee joint externally must include the use of Functional Electrical Stimulation (Figure 2). These externally applied electrodes provide a means of electrically stimulating the muscles controlling the knee. Work has been done using electrical stimulation with and without forms of external knee support with mixed results. This work is still considered experimental, but there is every indication that it may become a means of providing control of the knee in the paraplegic population.

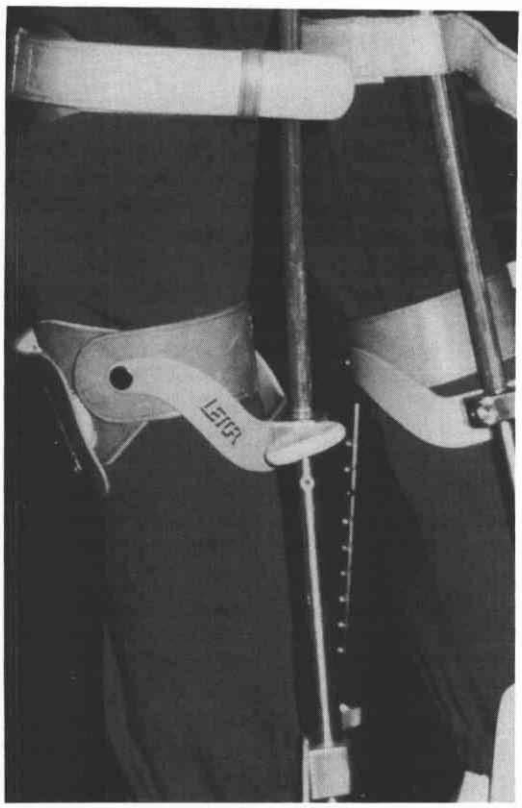

Figure 3. LETOR—Posterior telescoping rod bridges knee and prevents knee flexion.

CONCLUSION

A number of knee joint designs exist. Those developed from metal, i.e., stainless steel and/or aluminum, are best used when orthotically managing the paraplegic patient. Thermoplastic knee joint designs can be used in the unilaterally involved patient or when the problem is related to structural instability and not voluntary muscle control.

Knee joints are made stable by including mechanical locks or stops, by alignment techniques to insure that the ground reaction force is anterior to the axis of rotation, or by the addition of springs, elastic straps, or cords that dynamically extend the knee.

Ground reaction forces can be combined with the paraplegic's own intact anatomical knee joint to provide knee extension without orthotic extension above the knee joint (Figure 4). This has been used with limited success in selected pediatric paraplegic patients.

Present and future research may drastically alter components and materials used in the future. At present, however, the combination of appropriate prescription, components, fabrica-

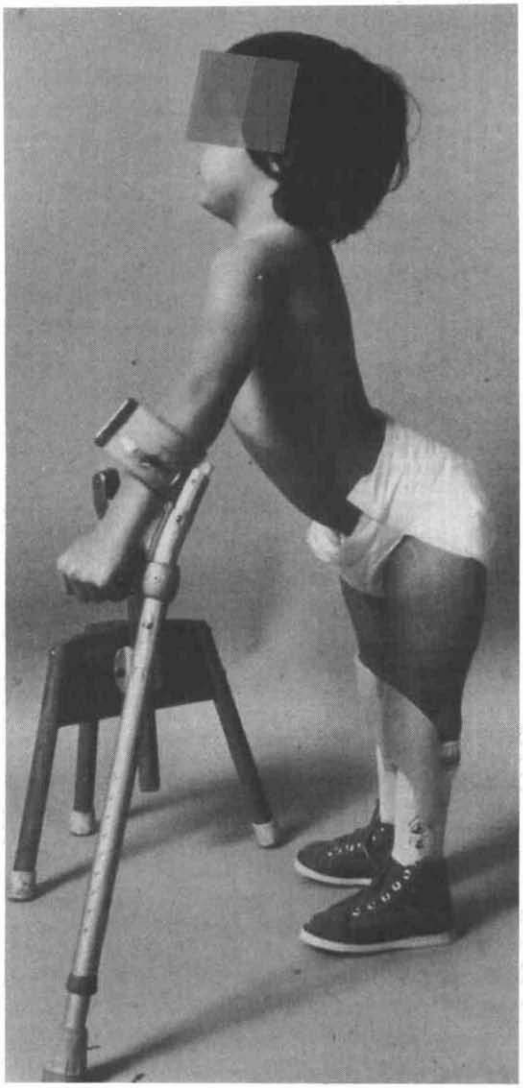

Figure 4. Floor reaction orthosis—posterior directed force on knee producing knee extension. Note hyperlordosis due to hip flexion contracture.

tion and fitting skills, along with skilled training in the use of an orthosis, will result in the potential for successful orthotic management of the paraplegic patient.

AUTHOR

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Clinical Prosthetics and Orthotics, Vol. 11, No. 2, pp. 95–100

The Anterior Shell Orthosis: An Alternative TLSO

by Carrie L. Beets, C.O.
Tom Faisant, R.P.T.
Vernon Houghton, R.T.O.
C. Michael Schuch, C.P.O.

INTRODUCTION

Postoperative spinal management has undergone progressive changes in recent years. The merits of early mobilization following spinal surgery are well documented[13] and it is now generally agreed that earlier mobilization leads to quicker and more successful patient recovery. The recent advent of DRGs and predetermined payment to hospitals, regardless of length of hospitalization, adds even more incentive to the concept of earliest possible mobilization.

Traditional approaches to postoperative spinal immobilization have been plaster body casts,[2,4,8,13] Jewett hyperextension orthoses,[3,5,6,7,8] and Knight-Taylor orthoses.[1,6,7] More recent approaches include the use of total contact TLSO's (body jackets), either with an anterior or posterior opening, or a bivalved, clamshell design.[4,5,6,7,8,9,11,12] Each of the above orthoses has inherent deficiencies with respect to very early patient mobilization attempts. Briefly, plaster casts lack total contact, lack volume adjustability, and do not promote or allow acceptable skin hygiene. Metal frame type orthoses such as a Jewett or Knight-Taylor do not control motion in all three planes, which is necessary for immediate postoperative mobilization. The ability of these orthoses to control lateral trunk flexion and/or rotary motion of the trunk is questionable. On the other hand, total contact TLSO's provide excellent control, but are very difficult to independently don and doff and, more important, they require rolling the patient into a prone position, or use of a Stryker frame, for molding. An additional deficiency of total contact TLSO's is they are too restrictive or confining, and actually slow the rehabilitation/recovery process by limiting range of motion necessary for independence.

DEVELOPMENT AND DESCRIPTION

In late 1977, Richard Rosenberger, C.P. (deceased March, 1985) and physicians with the Department of Orthopaedics and Rehabilitation at the University of Virginia Medical Center developed the "anterior shell" orthosis as an alternative TLSO, designed to address all of the above mentioned deficiencies found in these other orthotic approaches. As its name implies, the anterior shell orthosis is a TLSO that provides total contact coverage to the anterior three quarters of the trunk, with the anterior trimlines the same as those of any standard body jacket type TLSO, and the lateral trimlines just posterior to the lateral midline of the trunk (Figure 1). Suspension and immobilization are afforded by this total contact anterior section coupled with a Jewett type posterior pad with adjustable straps and a two inch wide Velcro® posterior strap across the sacral-coccygeal junction of the pelvis (Figure 2). Although quite flexible upon first impression, this TLSO becomes sufficiently rigid when properly tightened on a patient (Figures 3 and 4), deriving its strength and rigidity from the tubular principle. This orthotic design provides a three point pressure system which is effective from T5 to

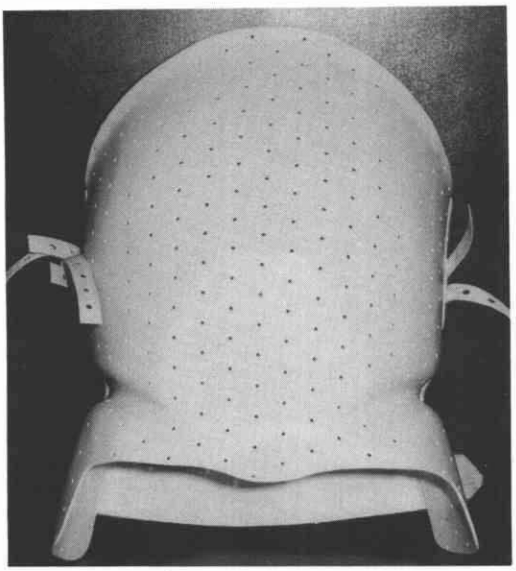

Figure 1. Anterior view of Orthoplast™ anterior shell orthosis.

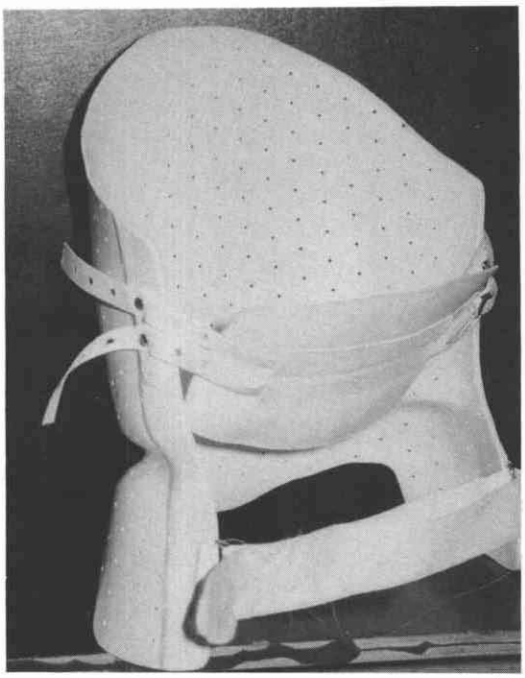

Figure 2. Posterior view of Orthoplast™ anterior shell orthosis.

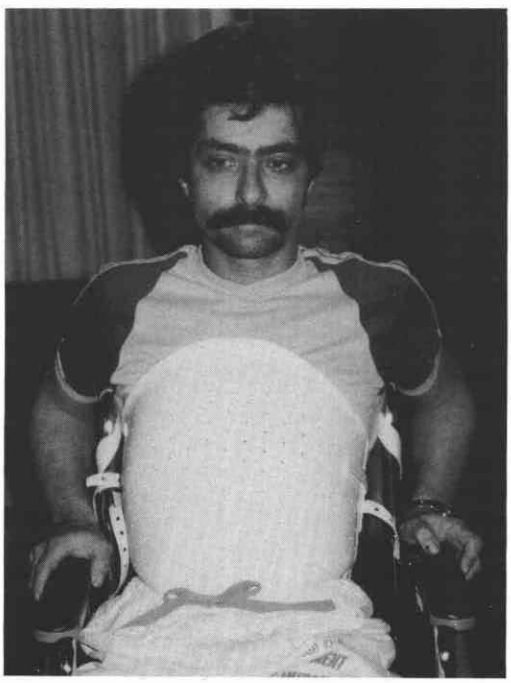

Figure 3. Anterior view of patient wearing orthosis.

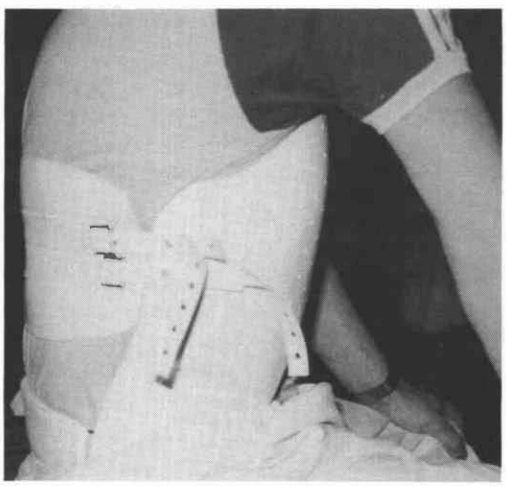

Figure 4. Lateral view of patient wearing orthosis. Note Jewett type posterior pad and strap arrangement.

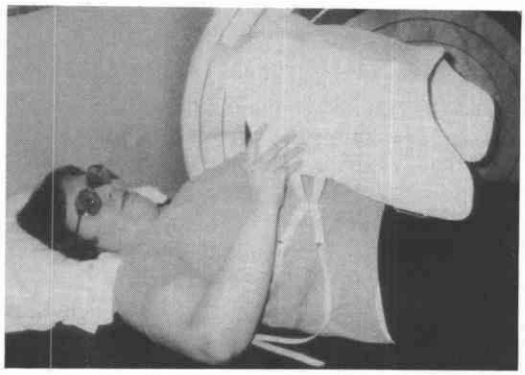

Figure 5. Patient in supine position donning orthosis.

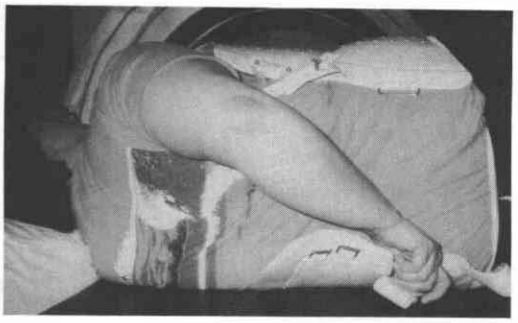

Figure 6. Patient, lying down, rolls to side and fastens the posterior pad and strap. Allowing for the posterior pad and strap to fasten on the same side facilitates donning and doffing in the lying position.

L5; however, a cervical extension can be added to the orthosis to extend its support to the upper thoracic region. Originally designed for postoperative spinal management following Harrington rod instrumentation secondary to traumatic injury, the anterior shell orthosis permits the cast impression to be taken with the patient comfortably supine without the need for proning or other patient movement.

ADVANTAGES

In addition to the advantage of not having to move the patient while casting, the anterior shell orthosis is felt to be superior to the bivalved and circumferential TLSO designs for postoperative management in other respects. Additional advantages offered by the anterior shell orthosis include ease of donning and doffing the orthosis initially for the nursing staff and later, the ability to independently don and doff the orthosis by the patient while in the supine position (Figures 5 and 6), ease of inspection of the surgical wound site without having to doff the orthosis, increased air circulation to the surgical wound site, and more efficient cooling due to less body containment within the orthosis. The anterior shell orthosis provides anterior, posterior, lateral, and rotary control, however, because there is no posterior section, the lateral aspects are slightly more flexible than in a circumferential design. This quality of slight flexibility facilitates maneuverability during transfers and activities of daily living, yet the orthosis provides sufficient external stabilization to protect the Harrington rod instrumentation.

INDICATIONS

As the advantages of the anterior shell design were proven with experience with postoperative patients, opportunities were sought for its use with other spinal diagnoses (Table 1). Indications for use of the anterior shell orthosis now include various vertebral fractures, treated surgically or non-surgically; vertebral degeneration and pain due to diffused malignancy; progressive kyphosis due to osteoporosis, ankylosing spondylitis, and neurological conditions; degenerative joint disease; and postoperative management of spinal stenosis.

EXPERIENCE

Over a period spanning 1979–1985, 232 patients were treated orthotically with the anterior shell; 137 of these patients were treated postoperatively (Tables 2 and 3). Over this seven year period, no postoperative patients experienced failure of surgical instrumentation while in the orthosis. During the initial development phase in 1978, only one postoperative patient experienced failure of his surgical instrumentation while in the orthosis.

Etiology of Diagnoses	
motor vehicle accident	102
fall	39
cancer metastasis	23
unknown etiology	16
osteoporosis	8
spinal stenosis	7
industrial accident	6
ankylosing spondylitis	4
gunshot wound	3
osteomyelitis	3
spondylolisthesis	3
degenerative arthritis	2
pedestrian hit by moving vehicle	2
rheumatoid arthritis	2
systemic lupus erythematosus	2
tuberculosis of the spine	2
anterior spinal artery syndrome	1
discitis	1
herniated disc	1
histoplasmosis	1
intoxication	1
old fracture non-union	1
plane crash	1
rock slide	1
wood stacking accident	1

Table 1.

TREATMENT REGIME

Current treatment of thoracic and lumbar spinal cord injuries at the University of Virginia Medical Center includes molding and subsequent fit and delivery of an anterior shell orthosis within a few days post-surgery. Patients are usually maintained supine in bed until the orthosis is fit and delivered, with rehabilitation beginning immediately after fitting and delivery. At two weeks post-surgery, patients are allowed unlimited forward leaning in the orthosis for level and uneven surface transfers (wheelchair to bed, wheelchair to mat, etc.). Once the basic transfers are mastered, appropriately supervised advanced wheelchair transfers are permitted, including wheelchair to floor, floor to wheelchair, ascending and descending stairs in a sitting position, and in and out of a bathtub. At three to four weeks post-surgery, patients are taught independent donning and doffing of the orthosis in the supine position.

TECHNICAL INFORMATION

Material Selection

At the University of Virginia Medical Center, the anterior shell orthosis is normally fabricated utilizing Orthoplast™. This thermoplastic material offers quick and easy fabrication that permits removal from the mold immediately after cooling without risk of shrinkage or other distortion. This allows for quick fabrication and delivery of the orthosis. Other noteworthy advantages of Orthoplast™ include preventilation for air circulation, light weight, and due to its low temperature thermomolding properties, it is easily adjusted or modified in hospital and clinical settings. In cases where the orthosis is going to be used definitively, thermoplastics such as polyethylene or Vitrathene are used in lieu of Orthoplast™.

Patient Molding

To cast a patient for an anterior shell orthosis, a piece of 12 inch wide stockinette is split lengthwise and placed over the patient with the edges of the stockinette tucked under the patient to prevent shifting during casting. A piece of narrow stockinette is passed carefully under the patient in the lumbosacral region of the back and through to the other side. The two ends are pulled tight over the iliac crests, tied off, and placed under tension as for pelvic traction (Figure 7). Indelible anatomical markings are made and include the xiphoid process, sternal notch, costal margins, anterior superior iliac spines, and the superior border of the symphysis pubis. Plaster splints are then applied making sure to cover from the symphysis pubis to the sternal notch anteriorally and down to the surface of the table on the sides, being sure to follow the patient's contours. When hardened, the plaster cast impression is removed and sealed and the positive model is poured.

Model Modification

The positive model is modified in a normal TLSO modification fashion, including flattening the anterior lower thoracic and abdominal area for increased intraabdominal pressure and defining the area above the iliac crests for

Patients Treated With Anterior Shell Orthosis								
	1979	1980	1981	1982	1983	1984	1985	TOTAL
Post-surgically	7	19	25	19	15	23	29	137
Non-surgically	6	9	11	11	11	25	22	95

Table 2.

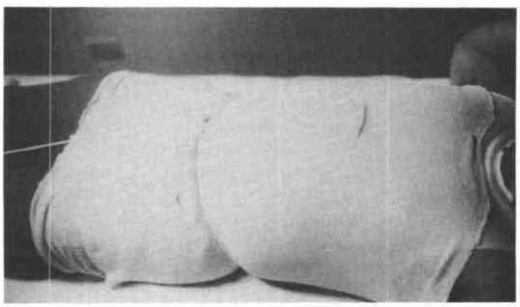

Figure 7. Patient, in supine position, is ready to be casted. Patient does not have to be rolled or turned to complete casting.

good suspension on the pelvis. Plaster build-ups are added over the anterior superior iliac spines if the patient is thin. The lateral posterior border is extended two inches in the posterior direction from the iliac crests inferiorally, to cover the gluteals laterally and increase lateral stability.

Because the anterior trimline of the orthosis extends to within an inch of the sternal notch, female patients require design variations in the model modification and the subsequent orthosis. For large busted female patients, an opening is frequently designed in the breast area to free the breasts. For smaller busted female patients, the breast area is built up on the plaster model to permit room for the breasts in the orthosis with the patient upright. In both situations, the area superior to the breast area is reduced on the plaster model to ensure good contact within the orthosis; also, the area superior to the breasts is reinforced in the fabrication process to ensure rigidity. When total contact for support and/or dispersement of pressure over a greater area is needed, as in cases of degenerative disease, such as osteoporosis, arthritis, and diffused cancer, the breast area is built up slightly on the plaster model and incorporated into a solid design in the orthosis.

Patient Population By Age		
Age	Males	Females
<20	29	10
21–30	47	13
31–40	20	12
41–50	16	11
51–60	22	17
61–70	6	9
71–80	7	10
>80	1	1
unknown	1	1
Totals	149	84

Table 3.

Fabrication Techniques

When molded with Orthoplast™, reinforcement is provided by a double thickness of Orthoplast™ in appropriate areas: the anterior superior and the lateral posterior edges. The metal anchor plates for attachment of the posterior pad straps are sandwiched in between layers of Orthoplast™ and later drilled and tapped for 8-32 screws.

If vacuum formed using a more durable thermoplastic, reinforcement can be provided with hybrid carbon composite inserts (available from Durr Fillauer). In this fabrication technique, the

metal anchor plates for the posterior pad straps can be mounted on the plaster model for incorporation into the vacuum formed shell.

In either case, the posterior pad is patterned after the Jewett orthosis posterior pad and has two sets of ½ inch dacron straps with 3/16 inch diameter holes, ½ inch apart in both ends for connection to the anterior shell. The posterior pad floats freely on the dacron straps, which are permanently attached to the metal anchorplate on the left side of the orthosis with 8-32 screws and have roller buckles on the right hand ends of the straps. The right side straps, which are attached under 8-32 screw studs, pass through the roller buckles and double back on themselves for adjustable tension control and attachment to the stud-heads of the 8-32 screw studs. The roller buckle system acts as a pulley system, thereby reducing the mechanical force needed to properly tighten the posterior pad.

The final component in the system is the two inch wide Velcro® sacral-coccygeal strap, which is permanently attached on the left side of the anterior shell, passes through a two inch stainless steel loop on the right, and doubles back on itself for a secure closure.

This adjustable closure system is described as was originally designed by Rosenberger, et al. It is not necessarily deemed to be the simplest. Any of the adjustable closure systems utilized in the available prefabricated spinal extension orthoses should provide a suitable alternative to the above closure system.

SUMMARY

The anterior shell orthosis provides quickly accessible orthotic support for early mobilization of patients with spinal cord injury and other diagnoses, allowing for independent donning and doffing with relative ease. Though sufficiently rigid to protect surgical instrumentation while boney fusion takes place, the anterior shell orthosis allows maximum maneuverability possible for a patient in a TLSO.

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Clinical Prosthetics and Orthotics, Vol. 11, No. 2, pp. 101–105

The Cast Off Valve: An Improved Method for Removing and Retaining Above Knee Casts and Prosthetic Sockets

by Albert F. Rappoport, M.A., C.P.

INTRODUCTION

The fabrication of a prosthesis continues to be a labor intensive process. The advent of prefabricated components, together with the use of central fabrication, has allowed many prosthetists to utilize their time more effectively. Time saving devices have always been welcomed by the prosthetic practitioner, especially when the quality of work is not compromised.

Removal of an above-knee socket from a plaster model is a common procedure in most prosthetic facilities. There are several methods for removing the socket from the cast. These methods will be addressed later in the text and the problems of each discussed. The most improved method is the Cast Off Valve (Figure 1). The Cast Off Valve uses compressed air, linking it directly to the above-knee socket (Figure 2). The female coupling of the air hose is attached to the male connector of the Cast Off Valve (Figure 3). The Cast Off Valve is then threaded into the suction valve housing of the above-knee socket. This method saves manpower, time, and energy by allowing removal of the socket from the cast in a matter of seconds. It is also effective in the duplication of any definitive above-knee suction socket. The concept is credited in its design to Judd Lundt, B.S.A.E., Assistant Director at UCLA's Prosthetic Education Program.

Figure 1. The Cast Off Valve.

METHODS OF REMOVING SOCKET FROM CAST

Several methods have been used, with varying degrees of success, in removing an above-knee socket from a plaster model. The oldest method involves breaking the plaster out of the socket with a cold chisel and hammer, or air chisel. This is a labor intensive process which is still practiced by many prosthetists (Figure 4). This process is not always necessary to facilitate the removal of a definitive socket.

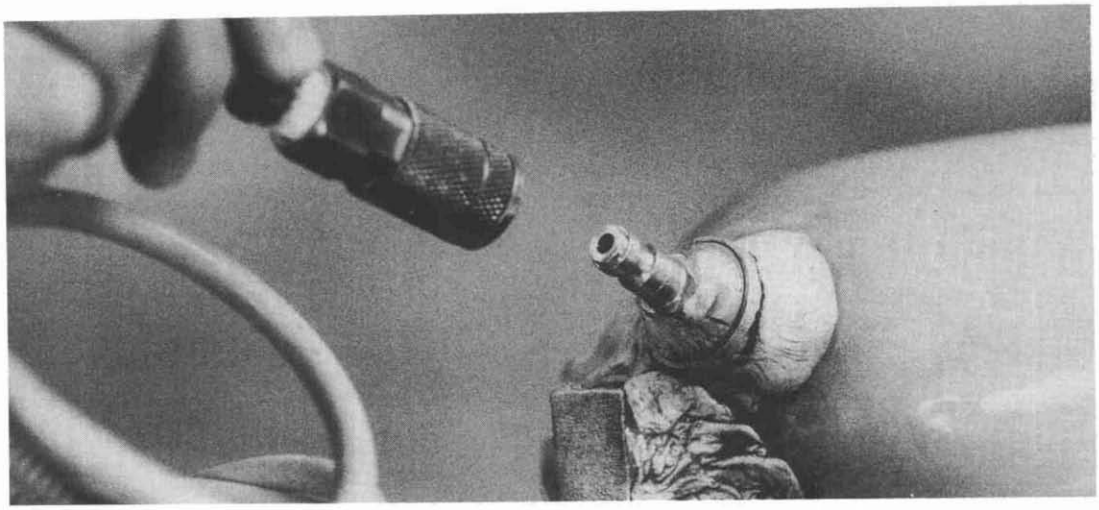

Figure 2. Female couple of air hose to male connector on Cast Off Valve.

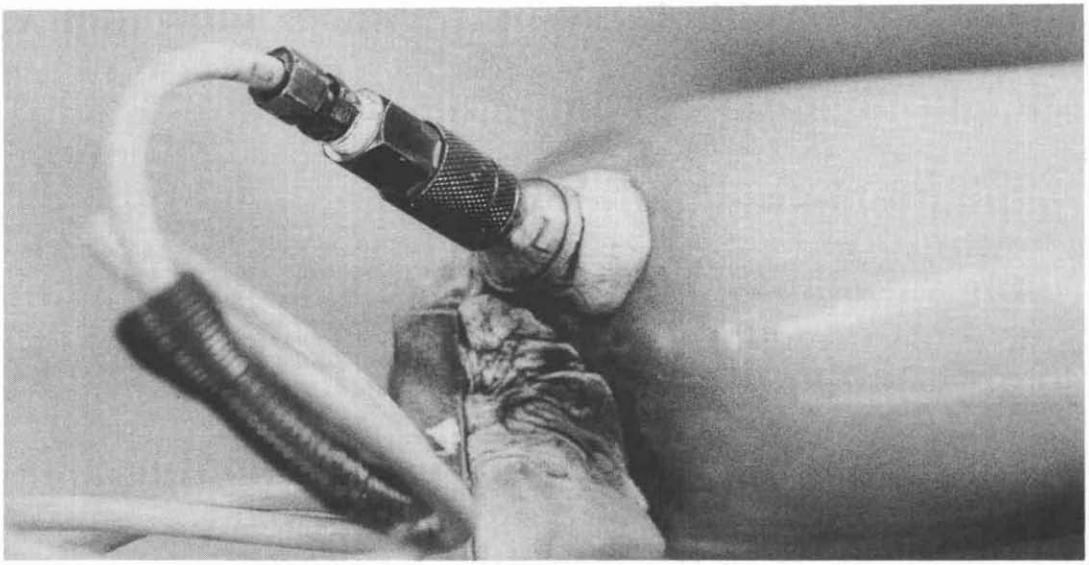

Figure 3. Cast Off Valve attached to female air hose coupling.

BIVALVING

Many times, the prosthetist would like to save the plaster model for further modification or reference. One approach to saving the model is to bivalve the socket with a cast saw (Figure 5). Once the socket has been bivalved, the cast can be touched up with minor plastic additions and used again. After the socket is bivalved, it cannot be reused. This process is not only time consuming, but can be eliminated in many circumstances.

COMPRESSED AIR

The use of compressed air is by far the most popular method. It saves labor, time, sockets, and casts. A newly formed check socket or

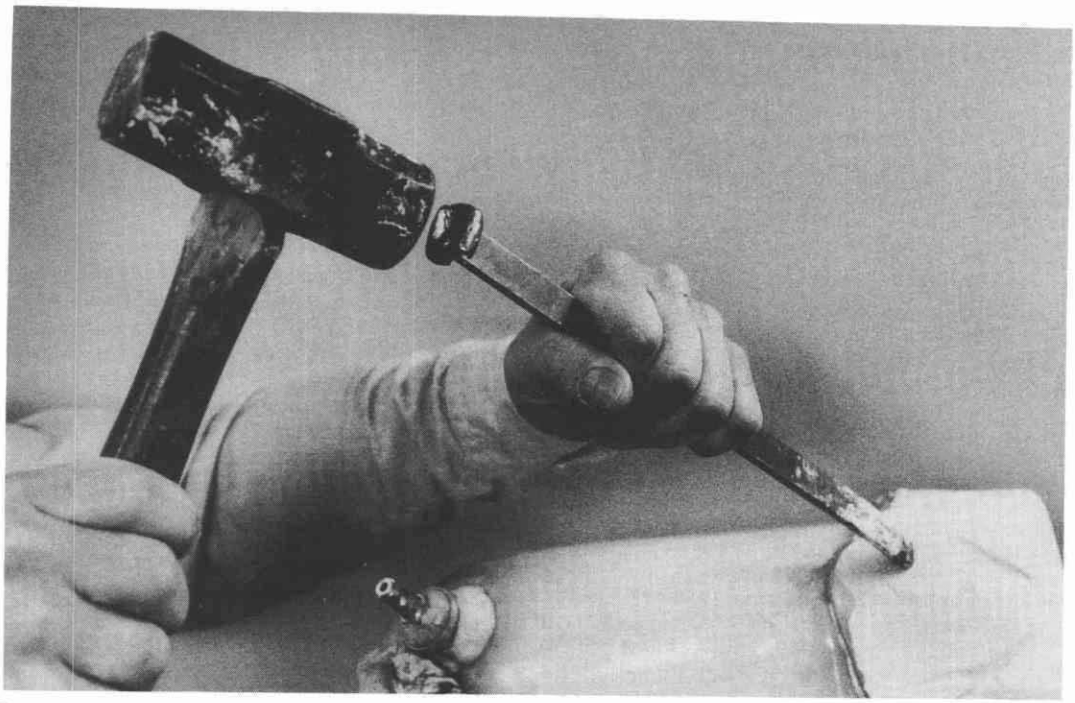

Figure 4. Age old method of removing socket by breaking out plaster by hand.

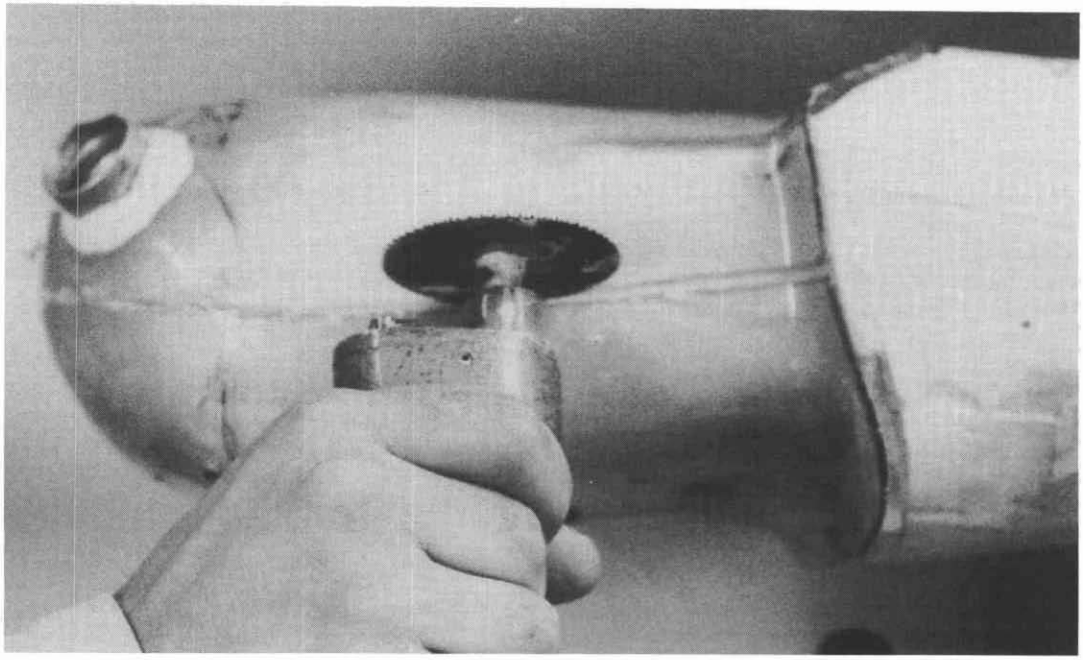

Figure 5. Bivalving socket to retain cast.

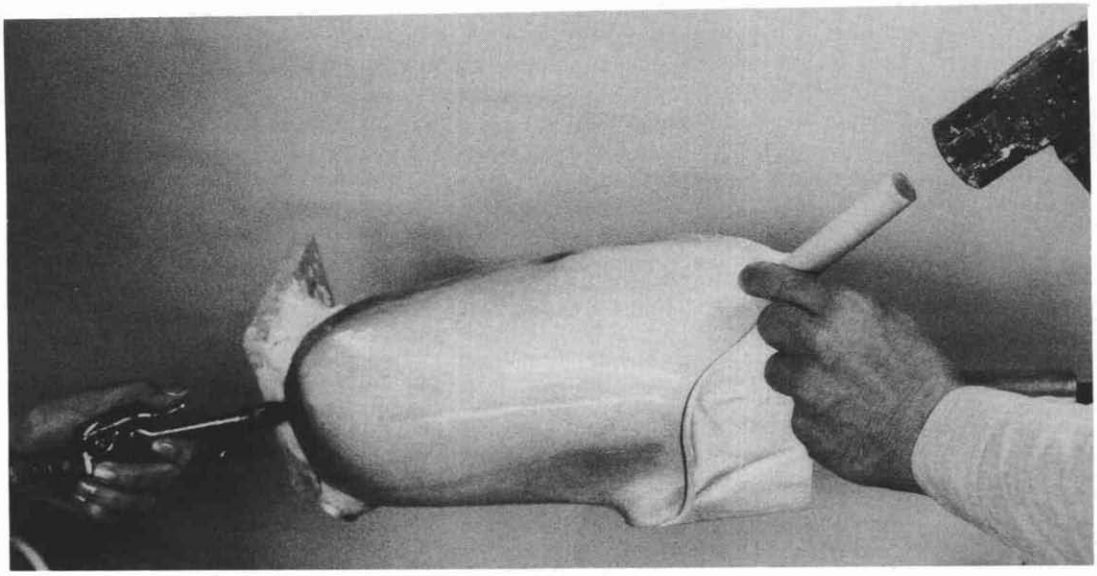

Figure 6. Removing socket from cast using compressed air. This two-person operation requires one person to use air gun to direct air through hole in bottom of socket and second person to tap proximal socket.

laminated socket may be easily blown off using an air gun. The newly fabricated socket must be trimmed just proximal to the desired trim line. A hole must then be drilled at the distal end of the socket to correspond in size to the tip of the air gun (Figure 6). One person holds the air gun with compressed air in the hole at the distal end of the socket, while the other person gently taps, trying not to fracture the socket, at the proximal brim. This is continued until the air is forced through the socket and assists in forcing the socket off the cast. Some radical socket shapes may prevent the ease of this technique, in which case it may be helpful to attempt this procedure while the socket is still warm or to refer back to the previously mentioned methods. The compressed air technique is an effective way to remove the socket from the cast without damaging either one. Two drawbacks to this method are: 1) it requires two persons to remove the socket, and 2) it is possible for air to leak through the hole where the air gun is held at the socket's distal end.

CAST OFF VALVE

The use of the Cast Off Valve can improve the effectiveness of the compressed air method (Figure 7). This improved technique can be employed whenever a valve housing is used in either a laminated socket or clear check socket. The Cast Off Valve is designed to fit the valve housing and link the air hose coupling directly to the socket. This approach allows a stronger air pressure to be obtained and little chance for air leakage. The use of this method requires only one person, freeing the hands of a second person who holds the air gun in the hole (Figure 6). First, the proximal brim of the socket should be trimmed with a cast saw. Once the Cast Off Valve is installed, the air hose can then be connected and the socket will blow off without any further effort. One may need to gently tap the proximal brim with a piece of wood dowling and hammer to assist the removal. (Note: certain radical socket shapes may prevent the use of this method.) In summary, the Cast Off Valve requires only one person to remove a socket from the cast with a minimum amount of effort, reduction of time and improved results over methods previously discussed.

SOCKET DUPLICATION

The Cast Off Valve also is excellent when an above-knee suction socket is to be duplicated

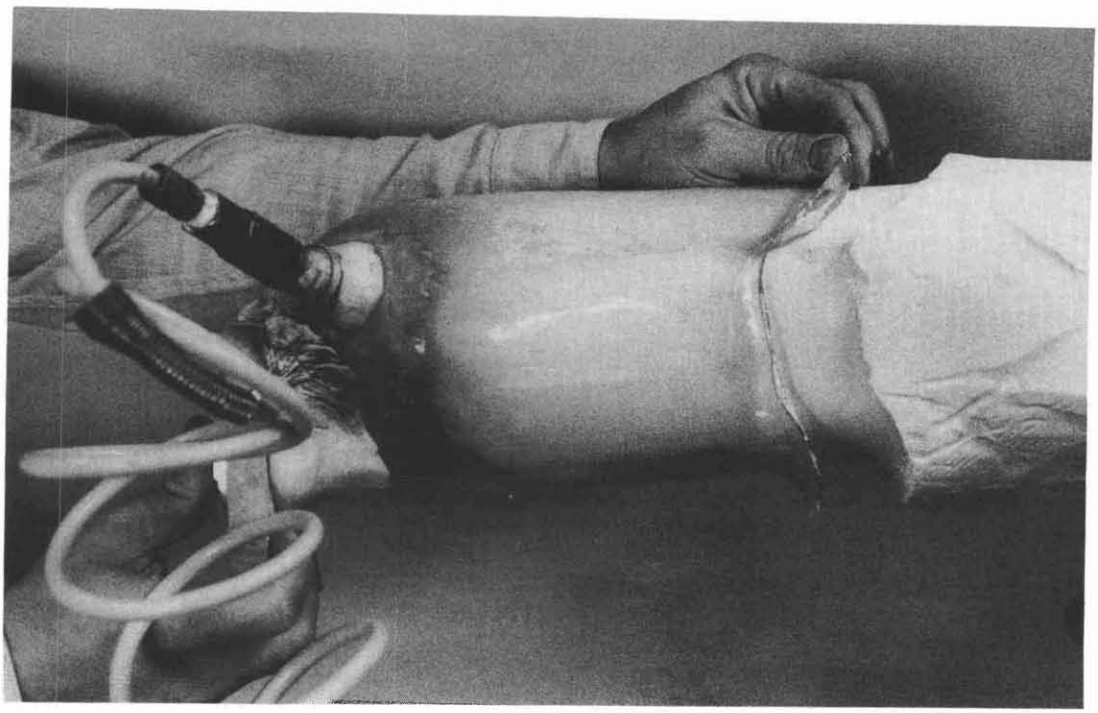

Figure 7. The Cast Off Valve is threaded into valve housing and air hose is connected to blow socket off with minimum effort and maximum results.

from a definitive limb. No longer is an alginate impression or use of duplicating foam necessary. The patient's socket should be filled with plaster and a holding pipe inserted once the plaster has set. The valve housing must be cleared of any material so the Cast Off Valve can be inserted. The air hose coupling can then be hooked up and the socket is blown off in a matter of seconds. The socket is duplicated exactly in plaster and ready for lamination or check socket fabrication.

SUMMARY

The Cast Off Valve has been well accepted and tested clinically with great success for the past two years by the staff at UCLA's Prosthetic Education Program and Prosthetic-Orthotic Laboratory. The UCLA prosthetic staff has found this device to be valuable, in many cases, in removing an above-knee socket in both quadrilateral and CAT-CAM designs. This method allows the cast to remain undamaged for further reference and can be useful when duplicating a definitive socket. When working with an appropriately shaped cast, the Cast Off Valve allows the removal of the socket from the cast with improved results from the previously aforementioned methods.

ACKNOWLEDGMENTS:

This work is supported by VA Contract #633P-1667 Rehabilitation Research & Developmental Funds. Special thanks to Shirley M. Forsgren for the photography on this article and to Diane I. Lyons for preparation of the manuscript. Special thanks also to Dr. Ernest M. Burgress for his continued support in the research and development of advancing prosthetics. Thanks to Christopher Hoyt, CP, David Litig, CP, Mark Yamaka, CP, Richard Boryk, CPO, and Kenneth Neal, O/P Technician for their clinical evaluation of the cast-off valve at UCLA's Prosthetic-Orthotic Laboratory.

AUTHOR

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Clinical Prosthetics and Orthotics, Vol. 11, No. 2, pp. 106–108

Early Mobility Aid for Non-walking Children

by Virgil Faulkner, C.P.O.
N. Walsh, M.D.
D. Currie, M.D.

INTRODUCTION

The early establishment of mobility in children born with multiple congenital amputations and limb deficiencies is of paramount importance. The child's inability to manipulate objects, explore the environment, and function independently in an upright position can result in limited cognitive development. Prompt intervention is necessary to prevent this degenerative cycle from compounding the child's disabilities. A dominant concept in the field of cognitive development is Piaget's theory which emphasizes the importance of object manipulation for successful, early concept formation.[3] Although children with multiple congenital amputations cannot manipulate objects or move about using their own limbs, they can develop early concept formation by observing the actions and words of people around them. However, because the child's exposure to these activities is often limited by the amount of time that an adult is willing to donate, it is not surprising that some of these children have not developed normal cognitive functions.

Currently, devices used to provide mobility to most children with multiple limb deficiencies fall into three categories:

1. A socket fitted to a base with small wheels or casters (Figure 1).[2]
2. A pylon-type swivel walker (Figure 2).[4]
3. An electrically powered cart (Figure 3).[5]

All three of these options present problems that often cannot be overcome. The socket on casters[2] requires upper limbs or prostheses for propulsion. The swivel walker[4] (which was popular in Australia and Canada during the late 60's and early 70's, but was not widely used in the United States) requires great energy expenditure. Also, as the child grows and the center of gravity is raised, the walker may become dangerous. The electric cart[5] has provided the best opportunity for mobility to this group, but it is not widely used because each cart must be custom fabricated at a specialized center with most adjustments and repairs made at that center. Initial costs, as well as the costs of returning it to the center, often are prohibitive.

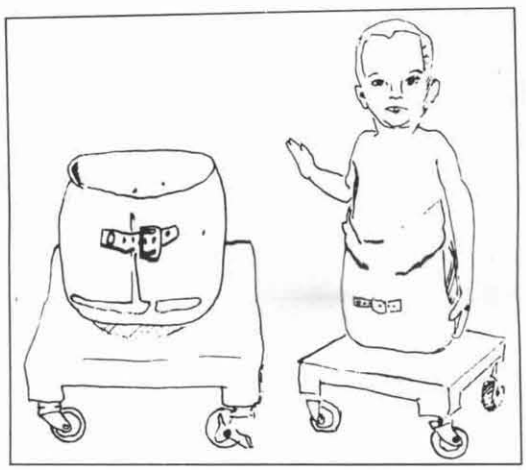

Figure 1. Socket mounted on caster base.

EVALUATION

The Rehabilitation Engineering Lab (REL) at The University of Texas Health Science Center at San Antonio recently was asked to help evaluate a two-year-old congenital amputee with bilateral upper limb amelia, hip disarticulation on the right, and proximal femoral focal deficiency (PFFD) with hemimelia on the left.

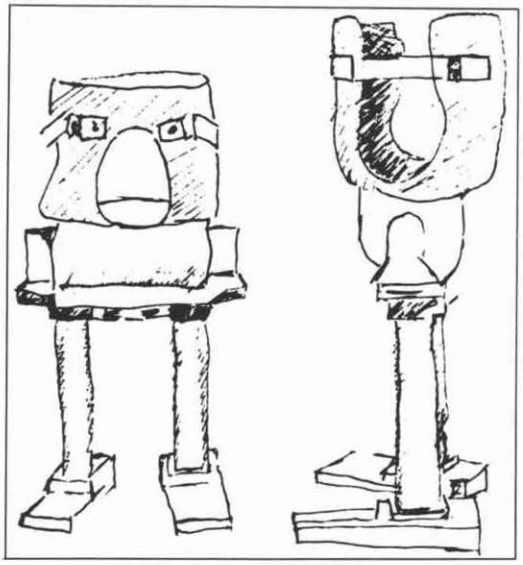

Figure 2. Swivel Walker.

Figure 3. Electrically powered cart, custom fabricated.

The child could move by log rolling. Toys could be manipulated to some extent by head, neck and trunk movements, but most toys had to be placed in position. The child could pick up objects with the mouth and with the toes. The child seemed to have appropriate cognitive development skills and was very curious about the environment. The referring orthopedist was not in favor of prosthetic fittings at this time.

After the initial interview with the child and family, the rehabilitation team considered the available mobility devices. The limitations discussed above and the 120 mile distance of the family's home from the center made it necessary to examine alternative options. To solve the immediate mobility problems, we considered relatively inexpensive, commercially available electrically powered toy cars.

DESIGN PROCEDURES

The rehabilitation team wanted a commercially available system that could be delivered to the family the first visit with minimal customizing required. It was decided that a "joystick" system for total operation of the vehicle was the most appropriate way to proceed.

We decided that a vehicle produced by Hedstrom, Inc,[1] The Probe VI, had the most features suitable to our needs. These included size, weight, simple drive mechanism, and an electrical system. Also, it appeared that this vehicle would require minimal modification. This toy vehicle is a battery powered six wheel vehicle with a molded body. The vehicle comes complete with two six volt gel batteries, which power two six volt electric motors. The six wheel design provides good stability (Figure 4).

The joystick allows forward, reverse, right, and left turns. An additional advantage of the Hedstrom vehicle is the small turning radius made possible by the steering system. This system cuts power to the drive wheel on the side of the direction of the turn. When the joystick is in the forward or reverse position, equal power is applied to drive wheels on each side of the vehicle.

DISCUSSION

The child came to the REL for an introduction to the modified vehicle. The joystick was adapted so that the vehicle could be moved without the operator sitting in it. A safety strap and foam pad were added to aid in sitting balance. The child was able to operate the cart by remote control while sitting in the mother's lap. After a few minutes, the child was placed in the vehicle and soon was operating it (Figure 5).

Figure 4. Probe VI.

The family was instructed in the vehicle's operation and sent home to practice. The total retail cost of the cart was $170.00. This vehicle should be sufficient as a mobility aid for several years with proper training and supervision. A vehicle of this type can be used as a mobility aid for children aged 18 months to seven years.[6]

Early mobility has been provided to a child with multiple limb deficiencies by minimal modification of a relatively inexpensive toy, an electrically-powered vehicle. The device was readily acceptable to both the patient and family. Such devices can give small children with similar disabilities a new dimension of mobility and represent an easily affordable adjunct to their rehabilitation.

ACKNOWLEDGMENTS

Photography done by Cono Farias, Photographic Technician II, Radiology Department, University of Texas Health Science Center at San Antonio.

N.I.H. Biomed, Res. Sup. Grant, #S07 RR 05654 "A Breath Activated Switching Mechanism for the Electric Powered Prehension Orthosis."

Figure 5. Child in modified Probe VI.

AUTHORS

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[5] Sumida, C., Y. Setoguchi, and J. Shaperman, "CAPP Electric Cart: Recent Developments," *Artificial Limbs,* 15, Autumn, 1971.

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Calendar

1987

April 24–25, Spring Meeting, New York State Chapter of the American Academy of Orthotists and Prosthetists, Ramada Inn, Binghamton, New York. Contact: Bryan Finley, CP, Program Chairman, Binghamton Limb and Brace Co., Inc., 142 Harry L. Drive, Johnson City, New York 13790; tel. (607) 797-1246.

May 4–13, UCLA CAT-CAM/Narrow ML Above Knee Prosthetics Course, Los Angeles, California. Contact: Timothy B. Staats, MA, CP, UCLA POEP, Room 22-46, 1000 Veteran Avenue, Los Angeles, California 90024.

May 13–15, Hosmer Electric Systems Workshop and Seminar, Memphis, Tennessee. Contact: Catherine Wooten, Hosmer Dorrance Corporation, 561 Division Street, Campbell, California 95008; tel. (800) 538-7748 or (408) 379-5151.

May 21–23, NYU course, the ISNY Below-Knee Flexible Socket, New York, New York. Contact: Registrar, Prosthetics and Orthotics, 317 E. 34th Street, New York, New York 10016; tel. (212) 340-6686.

May 27–29, NYU course, The Narrow ML Above-Knee Socket, New York, New York. Contact: Registrar, Prosthetics and Orthotics, 317 E. 34th Street, New York, New York 10016; tel. (212) 340-6686.

May 27–30, UCLA Total Surface Bearing Suction Below Knee Prosthetics Course, Los Angeles, California. Contact: Timothy B. Staats, MA, CP, UCLA POEP, Room 22-46, 1000 Veteran Avenue, Los Angeles, California 90024.

June 3–5, NYU course, The ISNY Below-Knee Flexible Socket, New York, New York. Contact: Registrar, Prosthetics and Orthotics, 317 E. 34th Street, New York, New York 10016; tel. (212) 340-6686.

June 4–6, Annual Meeting of the Association of Children's Prosthetic-Orthotic Clinics, Vancouver, British Columbia. Paper submissions: Francis J. Trost, M.D., Program Chairman, 2545 Chicago Avenue, South, Minneapolis, Minnesota 55404. Registration: Sidney Fishman, Ph.D., c/o NYU PGMS, 317 E. 34th Street, New York, New York 10016. Information: Yoshio Setoguchi, M.D., Child Amputee Prosthetics Project, UCLA Rehabilitation Center, 1000 Veteran Avenue, Room 25-26, Los Angeles, California 90024.

June 5–7, AOPA Region IX, COPA, and the California Chapters of the Academy Combined Annual Meeting, Doubletree Inn, Monterey, California.

June 8–17, UCLA CAT-CAM/Narrow ML Above Knee Prosthetics Course, Los Angeles, California. Contact: Timothy B. Staats, MA, CP, UCLA POEP, Room 22-46, 1000 Veteran Avenue, Los Angeles, California 90024.

June 12–14, Association of Cytogenetic Technologists Annual Meeting, Estes Park, Colorado.

June 18–21, AOPA Region VI and the Midwest Chapter of the Academy Combined Annual Meeting, Embassy Suite, Indianapolis, Indiana.

June 19–23, RESNA '87, the 10th Annual Conference on Rehabilitation Technology, San Jose, California. Contact: RESNA, Suite 700, 1101 Connecticut Avenue, NW, Washington, D.C. 20036; tel. (202) 857-1199.

September 11–12, Ohio Orthotics and Prosthetics Association/Ohio Chapter, American Academy of Orthotists and Prosthetists combined meeting, "Bridging the Profession," Dayton, Ohio. Contact: Norma Jean Finissi, Executive Director, O.O.P.A./Ohio A.A.O.P., 4355 North High Street, #208, Columbus, Ohio 43214; tel. (614) 267-1121.

September 28–30, Hosmer Electric Systems Workshop and Seminar, Hosmer Dorrance Corporation, Campbell, California. Contact: Catherine Wooten, Hosmer Dorrance Corporation, 561 Division Street, Campbell, California 95008; tel. (800) 538-7748 or (408) 379-5151.

November 11–13, Hosmer Electric Systems Workshop and Seminar, Hosmer Dorrance Corporation, Campbell, California. Contact: Catherine Wooten, Hosmer Dorrance Corporation, 561 Division Street, Campbell, California 95008; tel. (800) 538-7748 or (408) 379-5151.

1988

January 25–31, Academy Annual Meeting and Scientific Symposium, Newport Beach Marriott Hotel and Tennis Club, Newport Beach, California. Contact: Academy National Office, (703) 836-7118.

February 4–9, American Academy of Orthopaedic Surgeons Annual Meeting, Atlanta, Georgia.

May 13–15, AOPA Region IX, COPA, and the California Chapters of the Academy Combined Annual Meeting.

1989

January 31–February 5, Academy Annual Meeting and Scientific Symposium, Wyndham Hotel, Orlando, Florida. Contact: Academy National Office, (703) 836-7118.

February 9–19, American Academy of Orthopaedic Surgeons Annual Meeting, Las Vegas, Nevada.

May 12–14, AOPA Region IX, COPA, and the California Chapters of the Academy Combined Annual Meeting.

1990

January 22–28, Academy Annual Meeting and Scientific Symposium, Hyatt Regency Hotel, Phoenix, Arizona. Contact: Academy National Office, (703) 836-7118.

February 8–13, American Academy of Orthopaedic Surgeons Annual Meeting, New Orleans, Louisiana.

May 11–13, AOPA Region IX, COPA, and the California Chapters of the Academy Combined Annual Meeting.

Hood Co. Announces Winners of *Clinical Prosthetics and Orthotics* Article Competition

The Academy Editorial Board, through the sponsorship of the Hood Company, Inc., a New York State Corporation, is proud to announce the winners of the 1986–87 *Clinical Prosthetics and Orthotics* Published Article Competition.

The prize for best article co-authored by an orthotics/prosthetics practitioner goes to Cindi Ford, P.T., Robert C. Grotz, M.D., and Joanne K. Shamp, CPO for their article "Neurophysical Above-Knee Orthosis," which appeared in *Clinical Prosthetics and Orthotics* Volume 10, Number 1.

The prize for best article by an orthotics/prosthetics student goes to Greg Moore, RTO for his article "An Alternative Technique for Fabricating Flexor Hinge Hand Orthoses Using Total Contact," which appeared in Volume 10, Number 3.

Both winners have received a $250 award made possible through the generosity of The Hood Company, Inc., 2225 Kenmore Avenue, P.O. Box 240, Buffalo, New York 14207.

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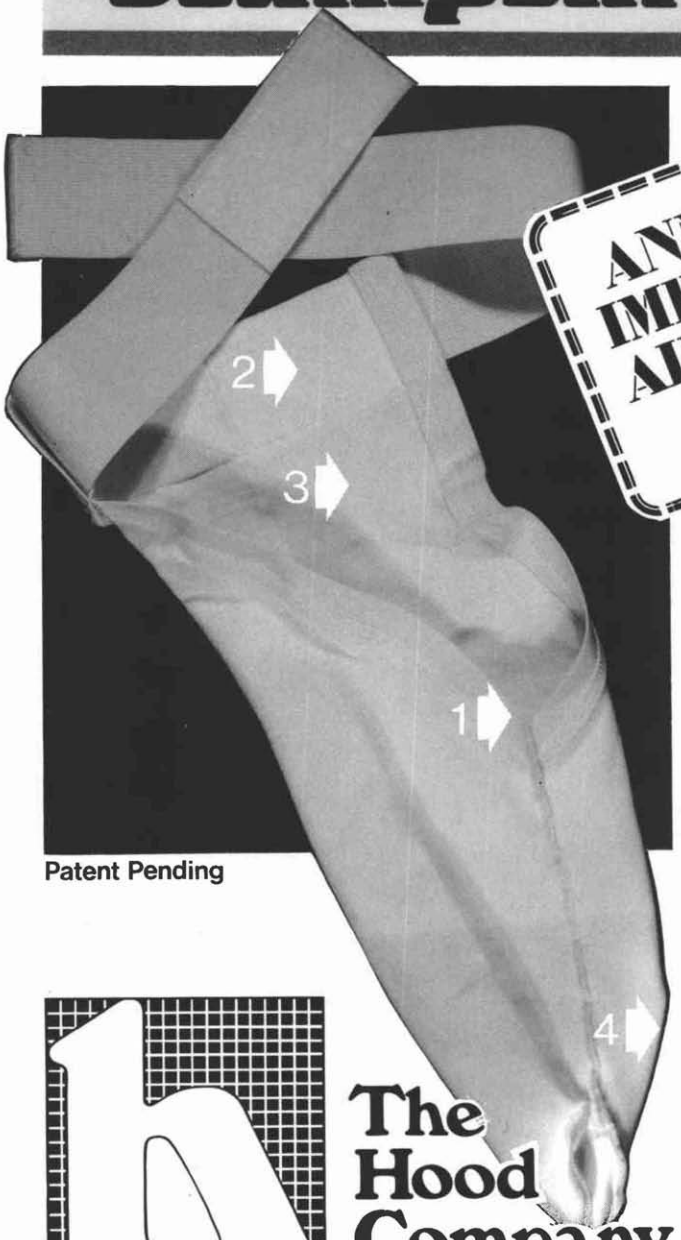

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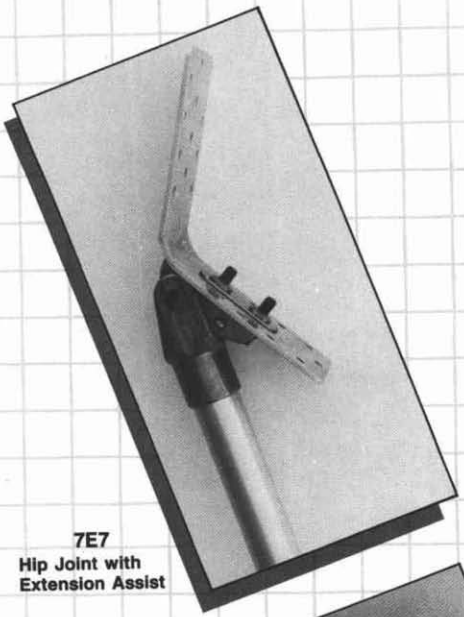

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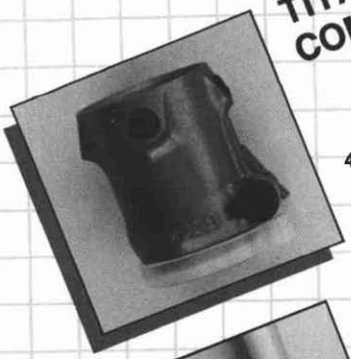

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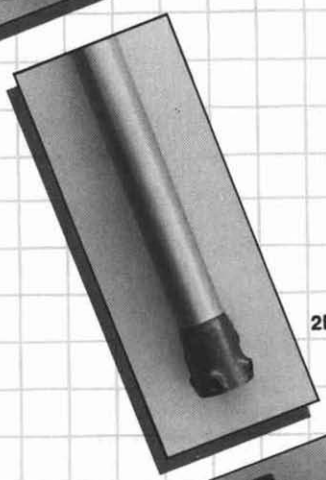

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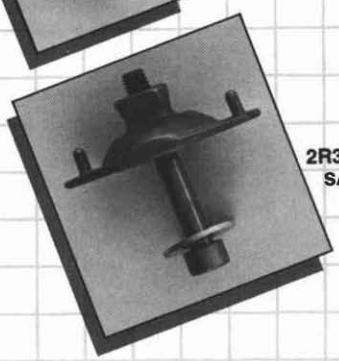

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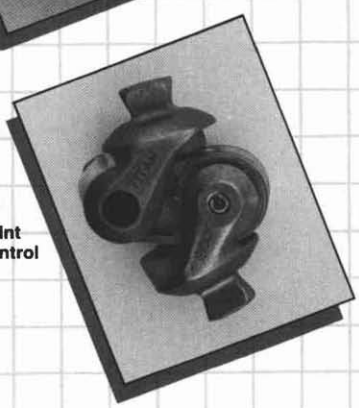

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