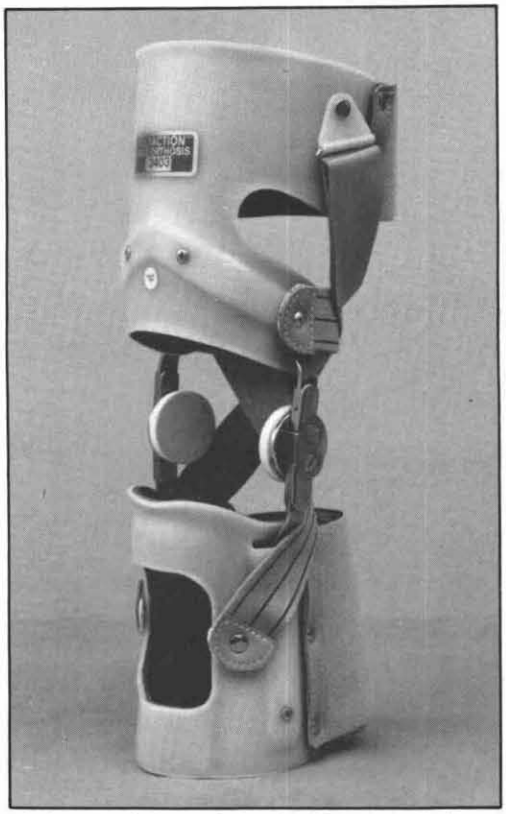
Clinical Prosthetics & Orthotics

Adaptive Seating

Volume 10, Number 4 Fall, 1986



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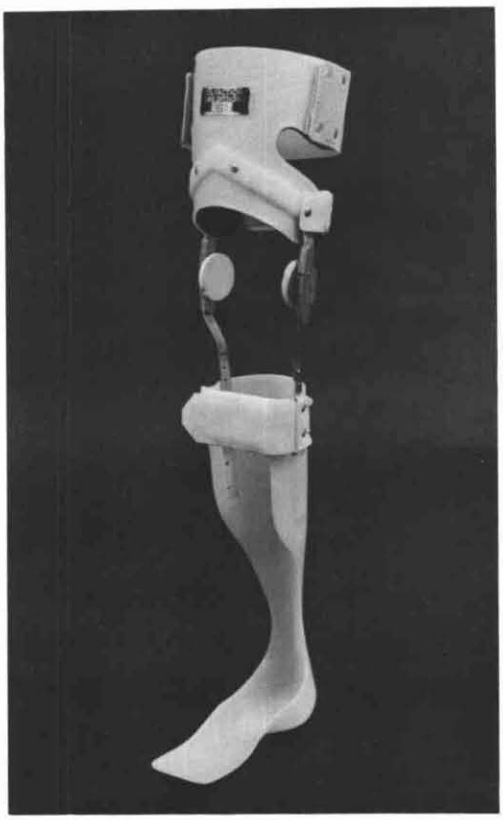

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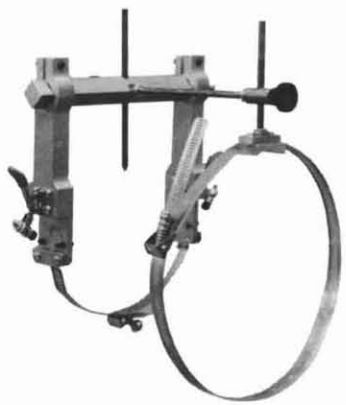

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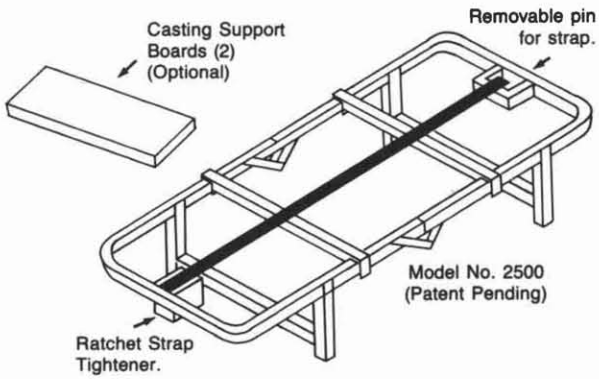

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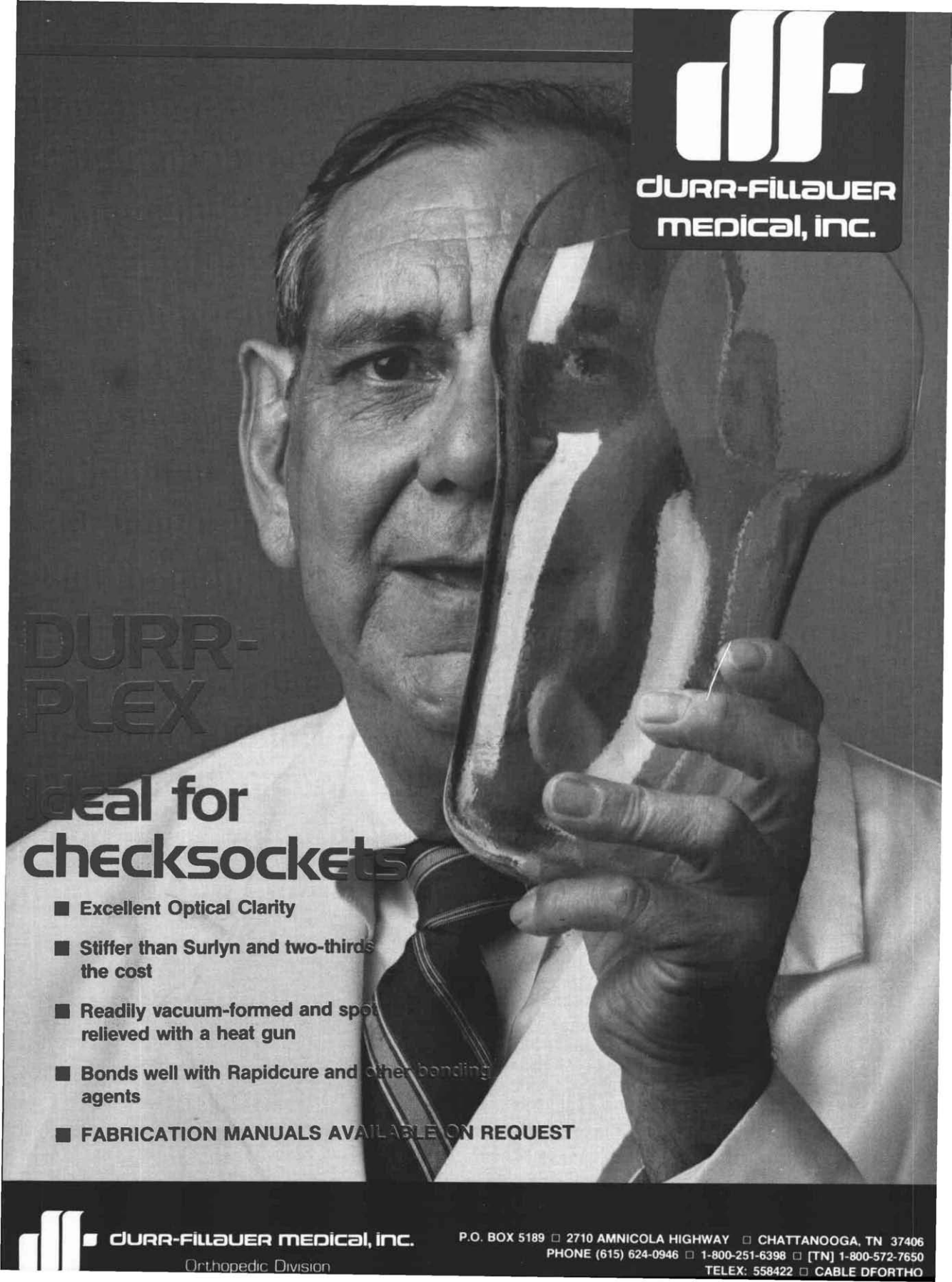
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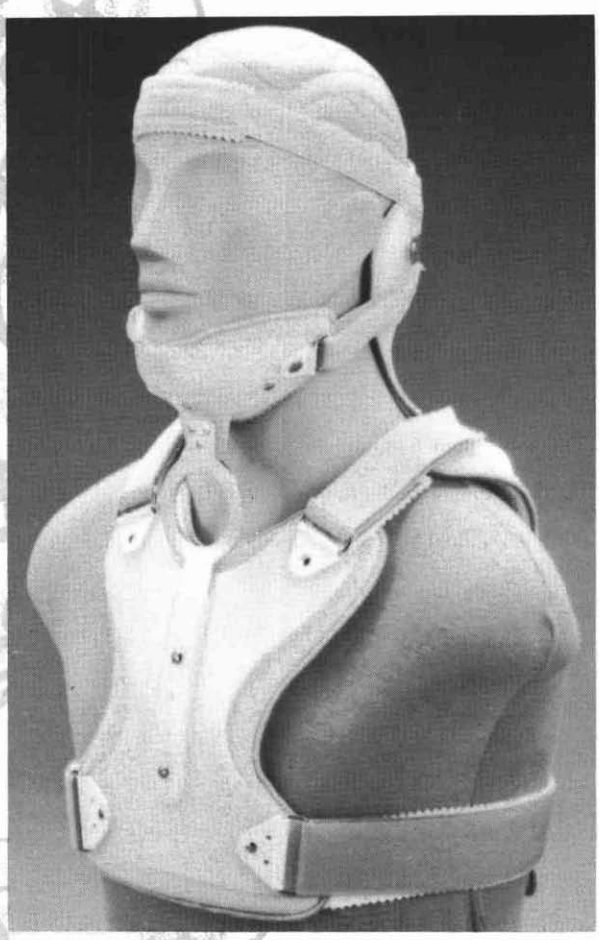

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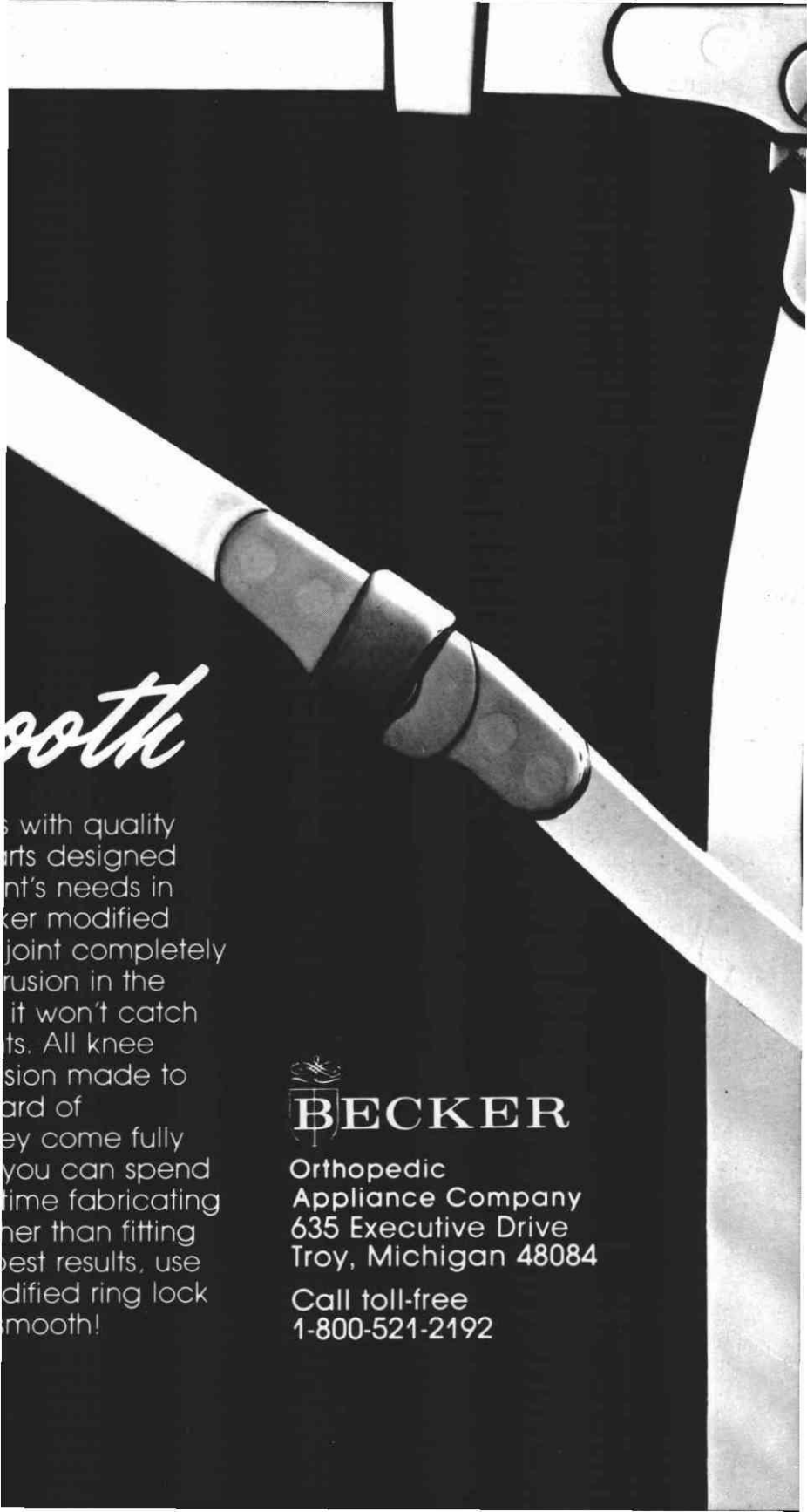
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Research and Development Considerations and Engineering Perspective

by Douglas A. Hobson, P. Eng.

BACKGROUND AND INTRODUCTION

Contrary to the impression given by a segment of current literature, the rapidly emerging field of specialized seating remains largely an art rather than a science. Established clinical principles, supported by a documented knowledge base are sparse, and clinical decision making remains largely subjective. That is, seating practice is not promulgated by an organized educational process.

Specialized seating is still in the 1950's era. At that time, significant advances in prosthetics and orthotics were being made. Prosthetics advancements included below knee and above knee socket fitting, fabrication, and alignment principles. In the 1970's, orthotics introduced vacuum formable plastics to the field. Only in the last five years has specialized seating offered more than one or two commercial options for individuals requiring custom contoured body support.

Specialized seating is still a comparatively young, but now a rapidly developing sub-specialty of rehabilitation technology.

It is probably of value to attempt to define what is meant by the field of specialized seating. First, it is a clinical process which attempts to maximize function through the provision of appropriate "body support" for a non-ambulatory person, usually in the seated posture, and usually in combination with a wheeled device, such as a wheelchair. The nature of the body support is dependent largely on the needs arising from the individual's disability. It can be thought of as providing seated body support in a manner that is usually less intimate and technically demanding than is required by conventional spinal orthotics (i.e., a body jacket).

Specialized seating has been an exciting area for involvement and research and development, especially during the last ten years or so. Engineers first became clinically involved in specialized seating in the late 1960's in Canada. During the intervening years, other professionals such as prosthetists, orthotists, therapists, and technicians throughout North America and Europe have been actively involved in specialized seating developments. This article attempts to focus on the research and development process that has led to the emerging principles and products that are now becoming common place throughout the delivery system, especially for individuals with cerebral palsy.

Perhaps of importance are the experiences that have shaped the views (and biases) of the author regarding the research and development process in the rehabilitation field. Firstly, early design experience in lower extremity modular prosthetics (Winnipeg, 1963–69), strongly reinforced the opinion that research and development should ideally take place in close proximity to an ongoing clinical commitment. Secondly, design and development must take place with a sense of reality towards the strengths and limitations of the manufacturing, marketing, and delivery system associated with the particular technology. This later view is the result of many frustrations, failures, and sometimes successes, in attempting to guide approximately a dozen "ideas" from conceptualization through clinical application over the past 15 years.

The R&D process for the field of rehabilitation engineering technology may be viewed as consisting of three interrelated phases of activity, a) research, b) design and development, and c) clinical utilization. The approach taken in this article will be to examine each of these activities as they relate to the development of principles and devices currently employed in the field of specialized seating. Emphasis will be given to applied clinical research versus basic research. The final section will address the current status of the field and suggest future needs for its continued growth. Along the way, developments familiar to the author will be used to illustrate key points. The flowchart (Figure 1) illustrates the process and suggests the primary outcomes from each step of the process.

RESEARCH CONTRIBUTIONS

The engineer, especially when entering new clinical areas, can be overwhelmed by the apparent opportunities to employ engineering principles towards what appear to be readily resolvable problems. With the passing of time, the realization emerges that most problems are much more complex than they first appeared and the best solutions involve creativity, simplicity of design, patience and a good deal of perserverance. Applied research, as it applies to technology and rehabilitation, could be defined as "a logical process which attempts to reduce chaos in favor of logical problems solving, during which time a few significant principles and related devices can be devel-

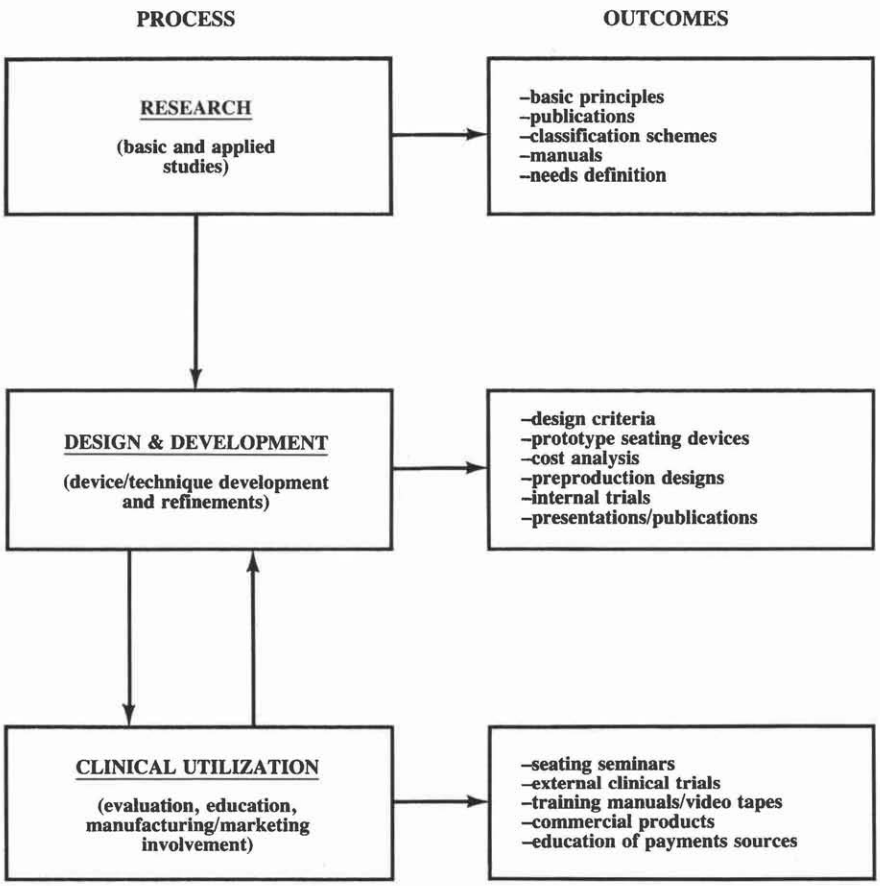

Figure 1. The three steps in the seating product development process, suggesting the major outcome for each step.

oped." This definition may appear rather non-scientific; however, most developments of significance to date have resulted from attempts to solve a morass of seating problems. From these attempts we see repeated positive results become positioning principles and related successful devices become commercial products.

At this point the question could be asked, What, of significance, has been learned about meeting the needs of individuals requiring specialized seating over the past 15 years? First, every person has a unique set of needs, therefore one generalized solution does not work for all. Second, it has been possible to group needs, or residual abilities, which can greatly assist in clinical decision making regarding the choice and provision of technical options. Third, there are three disability related (intrinsic) factors that dictate both research and clinical activities in specialized seating. These are a) lack of postural control (i.e., resulting from spasticity); b) existing or potential deformity; and c) the degree of loss of tissue sensation. The schematic diagram (Figure 2) combines these intrinsic factors in a three dimensional array. As can be seen, postural control can be graded as good, fair, or poor; deformity as mild, moderate, and severe; and sensation as normal, impaired, or asensitive. The groupings that result (Groups 1, 2, 3) give an indication of the degree of body support that the seating system must provide to compensate for the patient's intrinsic deficiencies. For example, a child with cerebral palsy, with a mild deformity, good postural control, and essentially normal sensation falls into Group 1. Individuals with Group 1 needs usually do not require custom contoured body support and often only need a simple seat insert (standardized modular insert) that can provide midline orientation and improve the fit of the wheelchair. Whereas a teenager with Duchenne Muscular Dystrophy, who has poor postural control, severe deformity, but normal sensation, would be in Group 3. This individual would require extensive custom contoured support, including pres-

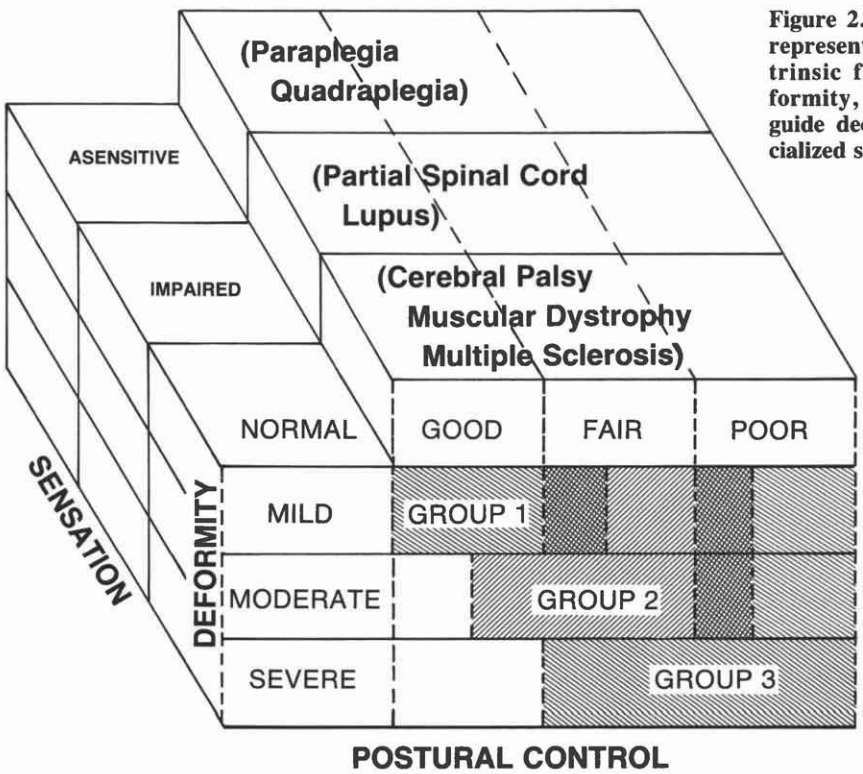

Figure 2. A three-dimensional representation of the key intrinsic factors (control, deformity, and sensation) that guide decision-making in specialized seating.

sure relief throughout the seating surface to accommodate for the discomfort associated with prolonged stationary sitting. A person with a low level spinal cord lesion (paraplegic) with only moderate deformity and fair postural control would fall into Group 2. In this case, some contoured support may be necessary to compensate for deformity and loss of postural control. Also, a primary concern may be the loss of tissue sensation, so pressure redistribution over the seat surface would be necessary.

Let us now go a step further and briefly look at a few disabilities in more depth. For example, individuals with cerebral palsy typically demonstrate a wide range of symptomatic intrinsic factors. It's usually obvious what group (i.e., Group 1, 2, or 3) they fall into for their general seating needs. However, what will be the short and long term postural needs for the child, how these needs can best be met through the seating system, and how the whole seating system must relate to the child's primary environments are all extrinsic factors that are best addressed by our therapy colleagues. That is, not only does one type of seating device not work for all, the manner in which it is configured for an individual, as well as how well it compliments the broader needs of the individual and the families are equally important. Experience has shown that specialized seating is best accomplished through a multidisciplinary approach in which the technical and therapy contributions are orchestrated within a medical environment, with a physician assuming primary medical responsibility.

In recent years, clinical research has begun to scientifically investigate the therapeutic principles related to positioning children with cerebral palsy. For example, Nwaobi[1] has shown that under certain conditions approximately 90° of hip flexion tends to minimize spasticity and optimize upper extremity function. More recent work by the same group[2] has also shown the importance of posturing in order to improve respiratory function in children with cerebral palsy. Present studies are looking at the potential contributions of posturing and seating support to reduce asymmetrical spinal muscle activity, which is thought to be a caustive factor in spinal deformity in the child with cerebral palsy.

Earlier work in Rehabilitation Engineering at Rancho Los Amigos Hospital with the spinal cord injured[3] established safe pressure level thresholds for the tissue over the bony prominences, such as the ischial, coccyx, and the greater trochanters. These thresholds provide guidelines for clinicians when fitting cushions for individuals who require pressure relief in order to prevent development of pressure sores. This early work has paved the way to more recent work that is now modifying and refining these principles.[4] Clinical programs employing these techniques have significantly reduced the onset and development of pressure sores. For example, Ferguson-Pell[5] has developed a computer program which assists therapists and others in decision-making regarding the selection and fitting of wheelchair cushions. This system combines and integrates much of the existing knowledge in terms of pressure sore prevention and guides the clinician towards a logical solution in which the chances for error are minimized.

Research in recent years has also developed other useful clinical tools. Again, for the spinal cord injured, there are now at least three commercially available devices (Scimedics TIPE, Oxford Pressure Monitor) that will measure and record the pressure that exists between the seated person and his support surface.[6] Other seating approaches use what is termed a ''simulator approach'' to assist in evaluation and fabrication of seating devices. For example, the MPI system[7] for cerebral palsy in children uses a multiadjustable frame and quickly detachable seat and back modules to allow the therapist to rapidly simulate the definitive seating arrangement. Tools of this type help in terms of therapy decision making and the subsequent communication with the technical staff responsible for the fabrication and fit of the device. Another research effort[8] is concerned with the collection of anthropometric data derived from taking measurements of a patient positioned in a subjectively good posture. This information will eventually be useful in the design of standardized componentry that will better match the dimensions and shapes of the individual.

Another outcome of research activities has been the classification of seating devices into five generic groups based on their methods of fabrication. Space does not permit detailed discussion of this classification scheme, especially since it has been published elsewhere.[9] The following table is a synopsis of the classification

scheme as it applies primarily to individuals with cerebral palsy. The table also incorporates the needs groupings discussed previously. This overall scheme has proven useful in helping inexperienced clinicians to better understand the key issues involved to match a client's needs with available commercial options.

In addition, the above classification scheme provides a framework through which a student in the field of specialized seating can begin to appreciate the differences that exist between the various technical options; and more importantly, what general needs each system is designed to meet. Further study involves learning the fabrication steps involved in the various systems, the positive and negative features associated each approach, and how features from various types can be combined to produce hybrid devices for meeting very specialized user needs.

Probably the most significant advancement is that both research and clinical experiences are now being brought together in the form of educational manuals[10,11,12] and instructional courses. This development is a major step towards establishing the body of knowledge that is so crucial if specialized seating is to progress from an "art" to a recognized field of professional endeavor.

DESIGN AND DEVELOPMENT

One of the obvious benefits of a research team working in close proximity to clinical activities is the potential for identification of "real" needs requiring technological intervention. Once these needs are identified, they then form the basis of design specifications which become the goals for the initial phase of the design and development process. Of all the endeavors involving rehabilitation engineering technology over the past twenty years, this step of defining what needs to be done has probably been the most poorly managed. There is probably no greater waste of technological resources than to solve problems for which there is either already an existing solution, or for which a solution cannot be sufficiently generalized to meet the needs of a commercially viable segment of the population.

Assuming a "green light" is still on after the "real" needs are identified, the next step is to develop a prototype solution, which in this context could be a technique, a clinical tool, or a seating device. The development is usually very "fragile" at this time, and the sooner it can be subjected to clinical trials and critique in a positive environment the better. Invariably, modifications and design refinements are required until a solution is developed that is acceptable to both the clinicians and their test subjects. Ideally, the development should then be exposed to wider critique within environments different from those in which the development took place. Also, manufacturing, marketing, and costing analysis should take place in preparation for the preproduction phase. Assuming all these steps yield positive outcomes, an initial preproduction run is made so controlled evaluations can be done in selected external environments. The results of the external evaluations should be carefully monitored, documented and made available to the production design team. Over the past six years, four such developments from the University of Tennessee Rehabilitation Engineering Program have gone through this process, some more rigorously than others. These developments, the Modular Plastic Insert, the Spherical Thoracic Support, the Foam-In-Place, and the Bead Seat System, are now all commercial products being marketed by three different commercial firms.

The final stages of the design and development process can vary depending on development and the resources of the commercial firm involved. In general, the market volume for seating devices is still relatively low. Therefore, it is important that the "front end" cost to the commercial firm be minimized. This can be accomplished in several ways by the development team. First, it is crucial that the design be "elegantly simple" so that it can be reproduced in relatively low volumes inexpensively. Secondly, design refinements and problems solving support should be provided well into the commercialization phase. Royalty arrangements and other "front end" type payments to the developer should be minimized and based on product sales. And finally, support in terms of providing educational materials, publications, and instructional seminars all assist in creating a receptive market place.

GENERIC SEATING DEVICES	*NEEDS GROUP*
Type I Noncontoured (ex. simple foam and plywood)	Group I
Type II Precontoured modules (ex. MPI, Pin Dot Modular System, Otto Bock MOSS)	Group II
Type III Multiadjustable (ex. Mullholland, E & J Postural)	Groups I & II
Type IV Custom Contoured a. Complex Foam & Plywood (ex. custom contoured foam cutouts) b. Traditional Orthotic approach (ex. plaster positive complete with plastic body jacket) c. Vacuum Consolidation (1 & 2 step) (ex. Bead Seat, Gillette Spinal Support, and DESMO) d. Foaming (1 & 2 step) (ex. Foam-In-Place, Contour-U, Canadian Posture) e. Shapable Matrices (ex. Clinical Engineering Design, London, England MERU-UBC)	Groups II & III

CLINICAL UTILIZATION

This final phase of the R&D process is most often neglected, since it is usually not very exciting to the development team. From the R&D perspective, this design activity addresses those features of the development that will make it an attractive alternative to existing methods or devices being used. Again, development of instructional materials, provision of evaluation prototypes to "trend setters" and conducting instructional courses have already been mentioned. However, these supporting activities in themselves are usually not the key influencing factor. The development team must address the question, Why would a service provider working within a particular service delivery system choose the new development over another technical option? The answer usually is that the service provider can provide a higher quality service at equal or lower cost. Therefore, the new development must provide improved function to the user, and possibly increased status for the clinic/provider, at costs that can be paid for by the payment structure in which the service is provided. Failure by the design and development team to recognize the realities of the delivery system in which the development must be marketed is probably a primary reason why so many developments fail to make the transition from laboratory to widespread clinical application.

CURRENT TRENDS IN SPECIALIZED SEATING

A 1985 survey of 26 facilities in 17 states[13] provides considerable insight into the state of maturity of the field of specialized seating. Of the 26 respondents, 12 were hospital based, six were state funded programs or institutions, and 8 were from private industry. The majority reported the use of plywood and foam technology (61 percent) or custom produced molded plastic parts (17 percent). The payment was received primarily from Medicaid, State Crippled Childrens Services, or private insurance carriers. The average number of clients fitted with new devices per year/facility was 185, with a total number fitted of 3,293.

The importance of this survey, in the context of design and development, is that the majority of the facilities reported the use of basic "bench" fabricated technology (78 percent). This is not surprising since the majority of the new developments have only been available commercially for less than three years, and related educational programs are just beginning to have a significant clinical impact. Continuing education programs supported by the American Academy of Orthotists and Prosthetists, the Rehabilitation Engineering Society of North America, and institutions like the University of Tennessee Rehabilitation Engineering Program, Newington Children's Hospital, and Elizabethtown Children's Hospital, and private firms, such as Pin Dot Products, and Mobility Plus have been the primary sources for training in the new concepts and seating systems. As these efforts are expanded to involve larger numbers of clinicians, the newer technology in seating will permeate into the service delivery system.

Of importance to the prosthetic and orthotic professions is that many of the professional skills and shop resources required to deliver improved specialized seating services are already in place. Also, specialized seating is now becoming recognized by many of the major third party payment sources as a recognized clinical service. The new commercial systems have been designed to be less labor intensive and to permit the provision of a quality product at a reduced cost. The overall result is that it is now feasible to invest in the education and inventory required to enter the field and expect to realize a return on that investment over a 2 to 3 year period. That is, specialized seating now presents a viable growth area for the prosthetic and orthotic field.

Projecting into the future, one may speculate as to what developments are likely to take place in the field. As far as design and development, it is likely that refinements to the newer commercial products will preoccupy the efforts and available development resources over the next two to three years. New and ongoing basic research will continue to develop or validate positioning principles for the cerebral palsy population. We should see refinement and expansion in the use of computerized expert systems, primarily by institutional settings that are doing larger volumes of evaluation and prescription of seating devices. Educational courses should become more available on a regional basis

through several of the participating professional associations. Hopefully, the American Academy of Orthotists and Prosthetists will continue its continuing education efforts in this area.

Probably the most urgent and difficult issue to be resolved is the further education of third party payment sources, so that seating services can be provided and reimbursed throughout the country. In this regard, initial efforts by the Rehabilitation Engineering Society of North America appear promising. Similar, and probably coordinated, efforts by other organizations such as the American Occupational Therapy Association, the American Orthotic and Prosthetic Association, and the American Academy of Orthotists and Prosthetists would be most timely.

In summary, research and development has made significant contributions to the field of specialized seating. This statement is based in the fact that there are not less than six new seating developments that have become available to the practitioner over the past five years. Basic studies, published articles, and manuals are establishing the foundation for educational activities that are becoming more widely disseminated. Third party payment sources have been slow to respond, but diverse efforts throughout the country have been successful at receiving reimbursement for seating services. In conclusion, more remains to be accomplished, and research and development can be expected to continue its contribution. Specialized seating is being transformed from an "art" to a recognized field of professional endeavor.

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[6] Scimedics, 170 Vander St., Units A & B, Corona, California 91720.

TIPE—Tee Kay Applied Technology, 11915 Meadow Trail Lane, Stafford, Texas 77477.

Oxford Pressure Monitor—International Medical Equipment Corporation, 11000 E. Rush Street, Suite 4, South El Monte, California 91733; (213) 350-1410.

[7] Modular Plastic Insert System marketed by Pin Dot Products, Inc., 2215 Belmont Street, Chicago, Illinois 60618.

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Adaptive Seating in Pediatrics

by Robert S. Lin, C.P.O.
Susan S. Lin, O.T.R.

Adaptive seating represents one of the most complex areas of orthotic management. No other area of clinical practice requires the degree of knowledge and application of biomechanics, design engineering, tissue physiology, wheelchair design and the clinical manifestation of the many neuromuscular disorders involved. No other area of management effects as many aspects of the patient's life and treatment programs initiated by other professionals. Therefore, it is imperative to solicit input from all members of the multidisciplinary team (Figure 1). The orthotist, physician, physical therapist, occupational therapist, educator, speech pathologist, social worker, psychologist, and wheelchair vendor must all take part in the prescription formulation (Figure 2). Unfortunately, formal training for the aforementioned professionals provides very little, if any, information for the evaluation, assessment, and design of adaptive seating systems.

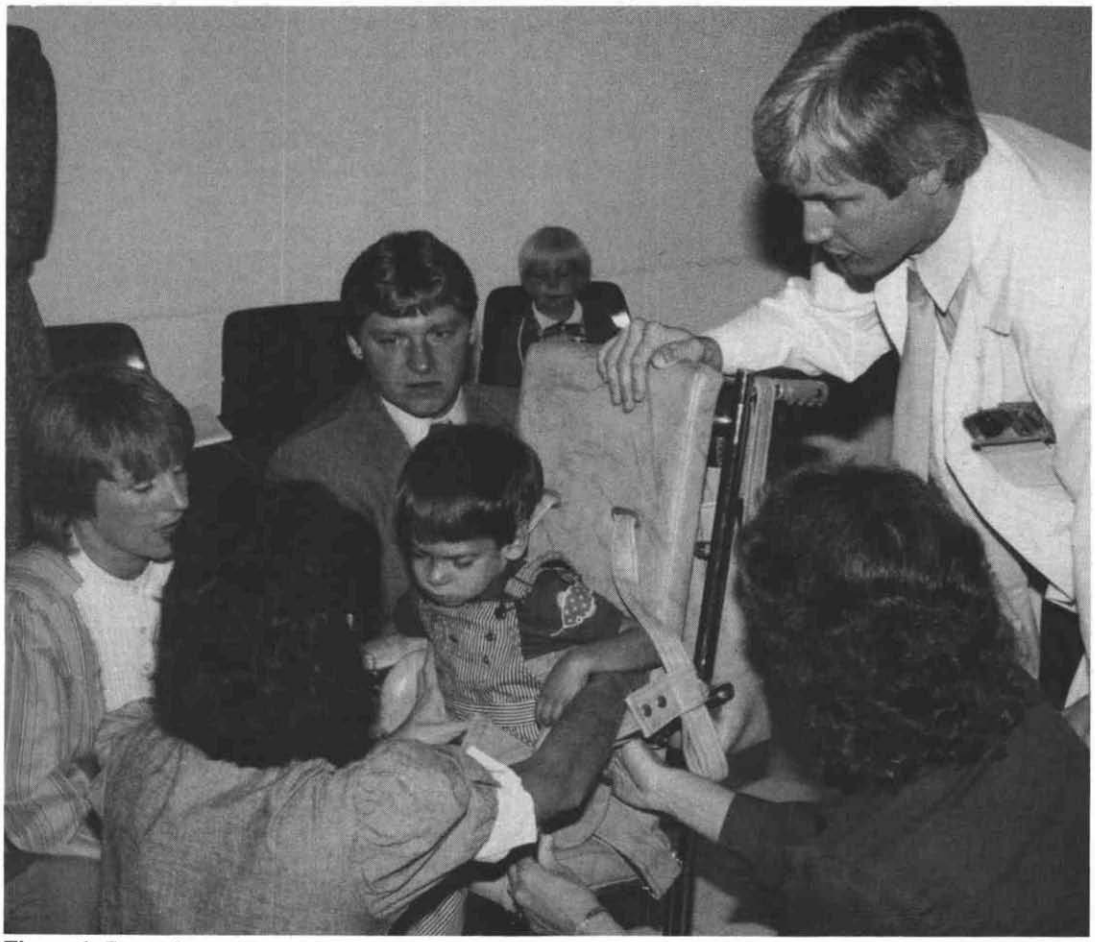

Figure 1. Input from all members of the rehabilitation team is solicited.

Figure 2.

DEVELOPMENT

To compound the difficulty of equipment provision, pediatrics offers additional complications that aren't as prevalent in management of the adult population. Because the child is still undergoing physical development and maturation, the clinical picture he/she presents is expected to change. Some of the changes are due to growth (longitudinal and/or circumferential) yet some are due to disease progression, developmental abnormalities, and psycho-social problems that result from an increasing awareness of the physically handicapping condition.

The adaptive seating system must be able to accommodate growth, environmental, and clinical changes in the child. This is particularly important in view of the funding restrictions on equipment replacement set by state or private payment sources.

EDUCATION

Another very important consideration in positioning a child is the child's educational goals and limitations. Aside from the physical barriers that a school may present, safe transportation to and from the school in a bus or van must be achieved. Few wheelchair bases are compatible with the lock down mechanism used by local transportation systems. This basic mechanical problem can hamper the educational process even before it begins.

Once the child is in the school environment, many subtle factors can influence the success and acceptance of the adaptive seating system. These factors include whether or not the child is mainstreamed or in a special education program; the physical design of the school such as elevators for multilevel institutions and overall wheelchair accessibility; whether the communication needs of the child are met in a group setting; desk height, which can profoundly effect actual integration; whether medical/nursing facilities are available; and the kinds of recreational provisions offered for physical education.

INFORMATION COLLECTION

Because the breadth of information concerning the patient can be extensive, there must be a mechanism to facilitate the collection of this critical data. It is imperative that the primary treating professionals provide this input, because of familiarity with the patient and preestablished goals.

The following *In-take* form was developed by author Susan Lin, O.T.R. in an effort to provide a concise patient data collection sheet. While the completion of this form can be time consuming, we have found that access to this information is essential (Figures 3, 4, 5, and 6).

ONE APPROACH TO ADAPTIVE EQUIPMENT PROVISION

In 1981, Newington Children's Hospital initiated its first formal Adaptive Equipment Clinic. The clinic is covered by seven members of the core team with three others forming the ancillary team. The core consists of a physician, orthotist, seating specialist, physical therapist, occupational therapist (who serves a dual function as the Adaptive Equipment Coordinator), speech pathologist, and social worker. The ancillary team is comprised of an educator, psychologist, and durable medical equipment vendor.

The clinic is held one morning per week, divided into four one-hour appointments. Every third week of each month is reserved for a recheck clinic and follow-up care is provided every six months. The follow-up appointments are one half hour long, with eight patients checked in a morning.

CLINIC DATE: _____

APPOINTMENT TIME: _____

ADAPTIVE EQUIPMENT INTAKE FORM

Please complete form and return to:

Date: _____

Individual Completing Form: _____

Relationship to Patient: _____

Patient's Name: _____ Sex _____ SS# _____

Patient's Address: _____ B.D. _____

_____ Age: _____

Parent's Name: _____ Home Phone _____

Parent's Address: _____ Work Phone _____

Language Spoken: Primary _____ Secondary _____

Interpreter Needed: Yes _____ No _____

Referral Source: _____

Reason For Referral: (state problem) _____

Funding Source:

Private Insurance Company: _____ Group #: _____ Individual #: _____

Title XIX #: _____

Other (please specify): _____

I. Medical History:

A. Diagnosis/Onset: _____

B. Orthopaedist: _____

C. Date Last Seen at Clinic or by Orthopaedist: _____

D. Pertinent History: _____

E. Medications: _____

F. Visual Acuity: _____ G. Hearing Acuity: _____

H. Conditions Which Affect the Patient: (please check)

_____ Vascular Problems/Edema
_____ Incontinence
_____ Respiratory Problem
_____ Skin Condition/Sensitivity
_____ Other: _____

_____ Seizure Disorder
_____ *mild*
_____ *controlled with medications*
_____ *severe*

I. Surgery Performed to Date: _____

_____

J. Further Surgical Intervention Planned: _____

_____

K. Skeletal Deformities:

Spine:

_____ Scoliosis _____ Kyphosis _____ Lordosis
_____ *fixed*
_____ *functional*
_____ *spine fused*
_____ *mild*
_____ *severe*

Pelvis:

_____ Hips Subluxed _____ Hips Dislocated _____ Pelvic Obliquity

L. Orthoses:

	YES	NO
Body Jacket (TCO)	_____	_____
TLSHO	_____	_____
Hip Abduction	_____	_____
HKAFO-Hip Knee Ankle Foot Orthoses	_____	_____
KAFO-Knee Ankle Foot Orthoses	_____	_____
AFO-Ankle Foot Orthoses	_____	_____

II. Physical Abilities:

A. Range of Motion: (joint limitations only)

1. Neck: _____
2. Upper Extremities: _____

_____

3. Trunk/Pelvis: _____

_____

4. Lower Extremities: _____

_____

B. Muscle Tone:	WNL	Hypertonic	Hypotonic	Athetosis	Ataxia
Head/Neck	_____	_____	_____	_____	_____
Trunk	_____	_____	_____	_____	_____
Upper Extremities	_____	_____	_____	_____	_____
Lower Extremities	_____	_____	_____	_____	_____

Additional Comments: _____

C. Pathological Reflexes as They Influence Positioning and Movement:

_____

_____

_____

III. Gross Motor Development: (please check)

A. Gross Motor Skill	Normal	Fair	Absent
1. Head Control			
a. prone	____	____	____
b. supine	____	____	____
c. sitting	____	____	____
2. Sits			
a. supported	____	____	____
b. unsupported	____	____	____

B. Transfers: (please comment) _____

_____

_____

C. Ambulation Status: (please comment) _____

_____

_____

D. Assistive Devices Used: _____

_____

IV. Fine Motor Skills:

A. Grasps/Releases Objects Volitionally with: _____ (R) hand _____ (L) hand

B. Hand movements uncontrolled/erratic: _____

C. Hand Dominance: left _____ right _____ not established _____

V. Functional Skills:

A. Activity of Daily Living Skills:

1. Feeding: _____
2. Dressing: _____
3. Hygiene: _____

B. Wheelchair Mobility:

1. Propels Manual Wheelchair Independently (Please specify type, i.e. L/R one-arm drive, projections, etc.): _____
2. Operates Motorized Wheelchair (Please specify type of control used): _____

_____

3. Dependent _____

C. Communication (Please check all statements which apply.)

1. Expressive Language:
   - _____ Intelligible Speech
   - _____ Non-speaking
   - _____ Expresses needs, wants by pointing, gesturing, and/or facial body movements.
   - _____ Expresses yes/no consistently and accurately by _____ .
   - _____ Functional expressive language skills.
2. Receptive Language:
   - _____ No apparent comprehension.
   - _____ Comprehends simple sentences.
   - _____ Recognizes pictures and/or objects.
3. Augmentative Communication:
   - _____ Uses sign language.
   - _____ Uses communication board.
   - _____ Uses electronic device; type of system _____ .

VI. Behavior: _____

VII. Educational Program:

Attends School/Program: _____ Teacher: _____

Mainstreamed: Yes _____ No _____

Cognitive Level: _____

VIII. Transportation:

- _____ Type of Car
- _____ Van-Standard
- _____ Van-Adapted for Wheelchairs
- _____ Public Bus

IX. Present Program:

	Therapist	Facility
O.T.	_____	_____
P.T.	_____	_____
Speech	_____	_____

X. Home Environment:

A. _____ Wheelchair Accessible

B. _____ Limited Accessibility (please specify width)
   flight of stairs _____ 2nd floor _____ narrow doorways _____

C. _____ Resides in Institution or Nursing Home

D. Equipment to be Used:
   Home _____ School _____ Work _____ Indoors _____ Outdoors _____

E. Description of Equipment Currently Being Used: _____

F. When Was Equipment Provided: _____

G. Who funded current equipment? _____

Prior to the first patient evaluation, the *Intake* forms for all new patients scheduled that day are reviewed and discussed. This enables us to establish a preliminary game plan as well as discuss certain confidential factors that may influence management. Formulation of the actual prescription occurs during the hour appointment, with various tasks assigned to appropriate team members to ensure follow-up of our recommendations.

Over the past five years, the NCH Adaptive Equipment Clinic has provided an ideal forum for patient and equipment evaluation and prescription. The aforementioned protocol evolved slowly and has worked very well considering our resources, patient population, time and cost constraints.

Those factors that have universal application are the need for a multidisciplinary approach, the need for follow-up appointments, and a sound understanding of seating principles.

The recent emphasis on adaptive seating has finally enabled the orthotist to assist in management of the entire spectrum of patients, not just those who are candidates for ambulation. The appropriate seating system can be a therapeutic tool which enhances the quality of life and serves as an adjunct to other rehabilitation efforts.

AUTHORS

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Susan Lin, O.T.R., is the Director of Occupational Therapy at Forestville Nursing Center and an Adaptive Equipment Consultant at Hudson Home Health Care. She was the primary developer of the Adaptive Equipment Clinic at Newington Children's Hospital and was the Hospital's first Adaptive Equipment Clinic Coordinator from 1981 to 1985.

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Seating for Children and Young Adults with Cerebral Palsy

by J. Martin Carlson, M.S., C.P.O.
John Lonstein, M.D.
Karen O. Beck, R.P.T.
David C. Wilkie, B.F.A.

INTRODUCTION

This paper will reflect the experience, perspective, and design rationale of one institution rather than attempt to give a comprehensive survey of the full spectrum of experience and designs.

Several examples are given and references made to Duchenne muscular dystrophy (D.M.D). The D.M.D. examples are used when they are particularly good illustrations of a general principle which helps complete our understanding of seating for children with cerebral palsy. For more information on our experience and rationale relative to seating boys with Duchenne Muscular Dystrophy, refer to the reference section.[2]

The study of seating has many facets (cosmetic, functional, economic, etc.) and many professional perspectives (engineer, therapist, orthotist, physician, manufacturer, etc.). Engineers tend to relate to biomechanics and the economics of standard design. Therapists are concerned with function, development, inhibition of spasticity, etc. Each medical specialist has a different predominant focus. In different settings, it is inevitable that availability of professionals, availability of funds, age and severity of client population culture, etc., vary, and these factors will direct the seating program. Another important factor is that orthotists have not traditionally been trained in the provision of special seating, most are not active in special seating, and in most communities, there is a shortage of orthotists. These realities are a major reason why pre-manufactured, easy to assemble, and adjustable designs have predominated in many regions. The potential for commercial success and profit for the manufacturer, the ability to provide a system without the involvement of orthotic professionals (who are scarce and often inexperienced in seating), and the need to minimize costs, all seem to be best served by the wide distribution of pre-manufactured designs. In many communities, that is the best option available at this time. However, there are communities and settings wherein the circumstances make it possible to have a higher average of custom fabricated designs.

To help you put this paper into perspective, we need to provide some information on the history of our seating program. The Orthotic/Prosthetic Laboratory at Gillette Children's Hospital became involved with seating in 1974. Our seating program developed out of almost ideal circumstances. Orthotic services were strong and there was a close working relationship between our orthotists, therapists, and medical specialists. Weekly clinics brought a steady stream of clients through our outpatient clinic where the team members worked together to solve both general and individual problems. Also extremely important was our strong tradition and mechanisms for follow-up, which provided us with excellent feedback. Our early entry into seating, and the growth of the program, quickly gave us a significant volume so that specialists could be assigned and efficient procedures developed.

Another factor bearing positively on our program is Gillette's extensive experience in spinal

orthopedics. The volume of patients and specialization of our staff enabled us to offer quality care at economical costs.

Although we have some experience with people of middle and advanced age, our experience at Gillette Children's Hospital is primarily with people from birth into young adulthood. This younger age group will be the focus of this paper. Our client population with cerebral palsy includes the full spectrum of severity, but the severe cases far out number the less severe.

It is important that we all endeavor to recognize and respect the various aspects, perspectives, and variable circumstances mentioned earlier. Two very different seating programs may offer equally excellent care, but both can be even better if they "compare notes." This paper is a compilation of our "notes."

FUNDAMENTAL GOALS

The seating systems we provide must benefit the impaired person, those who care for that person, and society. Balanced against that, every piece of equipment inherently carries costs and disadvantages. Our systems cannot be all things to all people, but we will most nearly approach the ideal by keeping our sights aimed directly at the fundamental benefits and goals, while we endeaver to minimize the negatives.

What are the fundamental goals? The main categories are outlined below.

1) Function
2) Orthopedic/Neurologic
3) Cosmesis
4) Safety
5) Economy

Function is primary. It affects a range of activities and benefits which can be best explained by examples: recreation for the child and family, making it easier for a care worker to feed a youngster, improving the child's field of vision, increasing his comfort, increasing the level of independence, etc. A functional seating system improves the childs development, decreases the amount of work required to take care of the child, and promotes a more enjoyable existence for the entire family.

Federal laws passed in the U.S. in the early and mid 1970's mandated that children be transported from their living environments to educational settings. Safe transportation necessitates secure seating. Ultimately, society benefits, both tangibly and intangibly.

From an orthopedic/neurologic standpoint, the ideal would be to prevent the progression of hip and spine deformities, and maintain body positions which reduce spastic reflex patterns. The benefits are better voluntary control, less severe deformity, less surgery, and a corresponding decrease in the work and cost of daily care. The advantages are perhaps most apparent to those of us who have visited state hospitals and have seen severely involved adult patients who were maintained only in recumbent positions during their earlier years. Positioning options for these adults are so severely limited that constant and expensive care is required to prevent ulcers and maceration. Also, hospitalization for those problems and pneumonia tend to be more frequent.

Cosmetically the ideal is a well camouflaged, hidden, or attractive seating system which helps the youngster sit upright with the head in a position to see and be seen. The aesthetic and emotional benefits of a cosmetically appealing seating system accrue to the child and everyone in his environment.

Comparing the costs of various seating approaches is difficult, because of the many costs which should be taken into account and the complexity of the various alternatives. We must take into account the cost of the seat, the cost of wheeled bases, repairs, frequency of replacement, and the cost of therapist involvement. The most important economic factor is the impact of a particular seating decision or system on the long range cost of daily care and health care. Long range costs must be considered, but they are very hard to estimate.

BIOMECHANICS OF SEATING

A normal head-trunk complex gets its stability from the spinal column, which acts as a controlled stack of compression elements, and partly from a multitude of muscles, which support it in different ways. The paraspinal muscles have a direct action on the configuration of the spine extention through lateral flexion and rotation. The abdominal (and to some extent, costal) muscles, in addition to

being direct skeletal motors, affect the spine's stability and configuration indirectly, but importantly, through their action on the viscera. Muscle action to constrict and control the circumference of the abdomen and thorax allow compressive body weight loads to be taken partly down through the fluid filled abdominothoracic cylinder rather than all acting down through the spinal column. This adds significantly to the stability of the torso. We must note that recent research by Nachemson, et al.[6] (indicating that the Valsalva maneuver fails to lower pressure in the intervertebral disks) challenges this classical explanation of Morris,[5] but does not propose a new analysis of abdominal muscle function in trunk stabilization. Swedish data suggests that we don't fully understand what the Valsalva maneuver consists of and how it functions biomechanically. (The Valsalva maneuver is a general tensing of abdominal muscles.)

The normal activity of sitting consists of a series of frequently changed postures. Each of those postures would be non-functional, uncomfortable, and even injurious if it were the only posture available to us and maintained for hours. It is the frequent voluntary change which makes those postures collectively safe, acceptable and tolerably comfortable for more than ten minutes. It is quite an undertaking to design a seating system in which our client can safely and comfortably sit, with little or no change, for a matter of hours. In the case of a person with cerebral palsy, the abnormally high muscle tone about the pelvis and thighs is the major reason this can be accomplished.

It is important to note that when a child has some limited postural alignment capability, that capability is greatest at the head and neck. There is less ability to control the pelvis (Figure 1). (This capability reflects the early developmental stages of an infant, but when we see it in the older child, it represents delayed or arrested development.) Arm-propping is typically used to stabilize the upper thorax for effective neck and head control. This illustrates two seating principles. The first is that the postural control and use of the superior body elements is dependent on the stability of body elements inferior to them. Second, the seat should bring the stability from the pelvis upward to meet the descending/decreasing voluntary stability of the client. Terminating stability too low will fail to maximize the child's function. Carrying stability too high will deprive the client of his full voluntary movement capability.

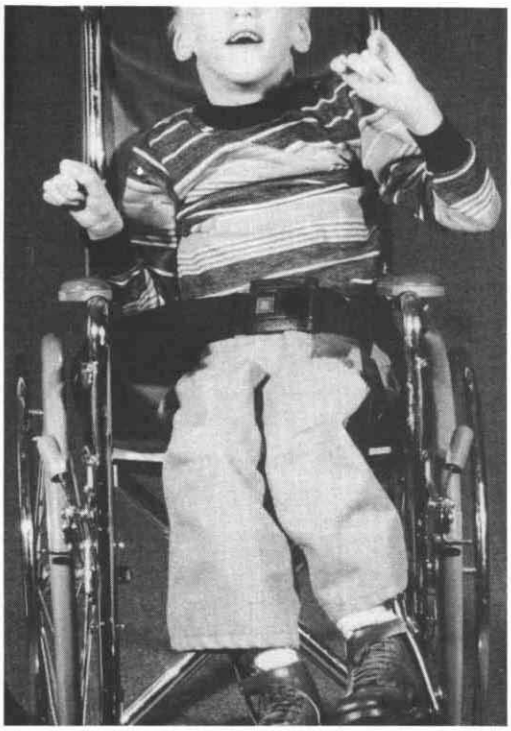


Figure 1. Alignment capability is greatest at the head and neck, less at the pelvis.

Since "normal" sitting postures are so variable and changeable, we cannot relate supported sitting postures to a specific normal posture. We must reason and choose a sitting posture which has the most advantages, and propose it as a "standard."

We choose the "sitting at attention" sagittal configuration (Figure 2), because it represents a mid-range spine configuration, it allows significant weight bearing on the proximal thighs as well as the bottom of the pelvis, it is a cosmetic posture (chest and head upright, facing outward), and it is a functional posture (head in a position to observe and thorax and shoulders forming a secure base for the neck and arms to move). In the sagittal plane, the sacrum is tilted anteriorly a moderate amount. There is moderate lumbar lordosis, thoracic kyphosis, and cervical lordosis. We would further propose that the "standard" posture consists of a pelvis level and the spine straight in the frontal plane.

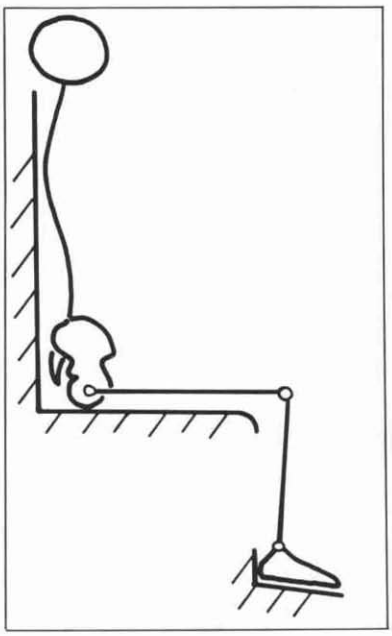


Figure 2. Sitting at attention represents a mid-range spine configuration.

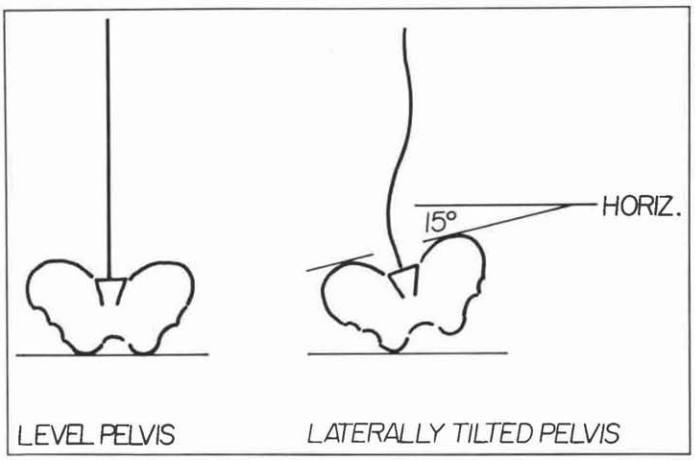


Figure 3.

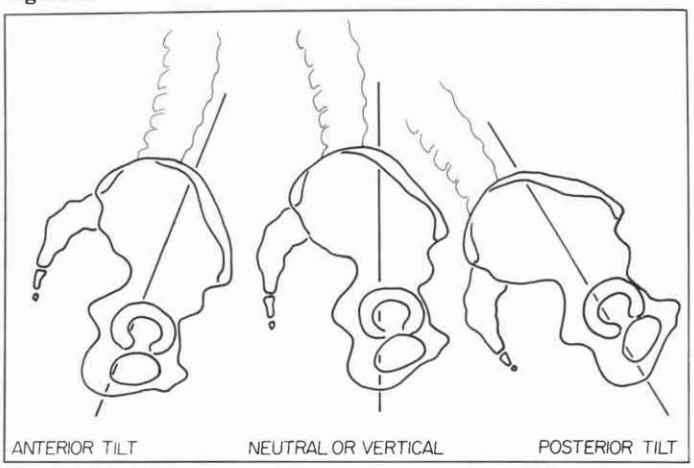


Figure 4.

When the left side of the pelvis is elevated, the pelvis is said to be "tilted rightward," and when the right side is elevated, it is "tilted leftward" (Figure 3). Likewise, in the sagittal view, the pelvis is "tilted posteriorly" or "tilted anteriorly" depending on which direction the upper parts of the pelvis are oriented relative to "standard" (Figure 4). In the transverse plane, if the right side of the pelvis is rotated forward relative to the shoulders, we would say the pelvis is "torqued leftward." We do not present this nomenclature as the most correct, but offer it for use in the absence of standard nomenclature.

Cerebral palsy is a disease that expresses itself in a wide variety of static and dynamic patterns, and we cannot go into the mechanics of all those variations. We will limit ourselves to a discussion of what, in our experience, is the most common combination.

Fortunately, even some of the children with severe cerebral palsy do not have a significant deformity or collapse in the frontal plane. This is not to say, however, that scoliosis is rare in this group. Scoliosis is quite common, and we see very severe cases. When we examine a child with scoliosis, we should evaluate whether or not the scoliotic collapse is aggravated by asymetric trunk muscle spasticity. We can expect to be much more effective at controlling a scoliosis deformity when asymetric trunk muscle spasticity appears not to be a significant factor.

One of the usual characteristics of scoliosis in neuro-muscularly impaired sitters is lateral tilting of the pelvis in the direction of the con-

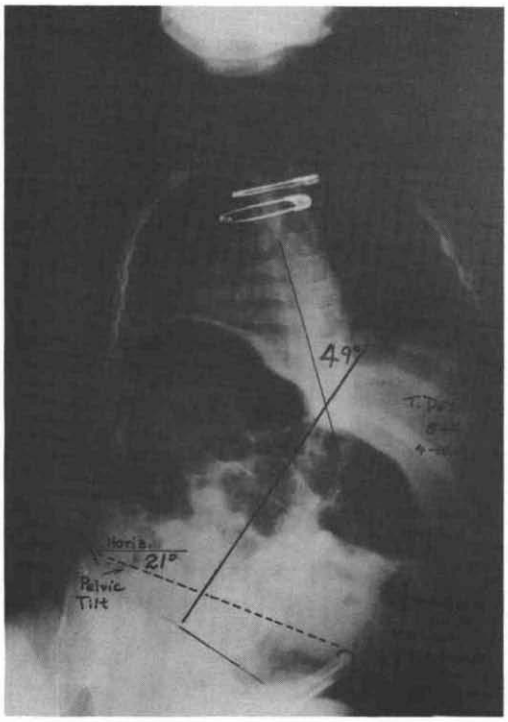


Figure 5. Lateral tilting of the pelvis in the direction of the convexity of the major scoliotic curve.

vexity of the major scoliosis curve (Figure 5). This is not surprising when we consider that pelvic orientation is usually not under voluntary control. This characteristic will become more interesting later as we discuss the various methods for generating spine stability.

There are several distinct biomechanical schemes for providing spine stability to resist scoliosis. These schemes do not, of course, operate exclusively in the frontal plane. Also, the employment of one scheme does not preclude the simultaneous employment of one or more other schemes. The first and most familiar of these is "three-point-force". We need not explain the principles of this scheme since they are so well known. However, it is appropriate to note that three-point-force schemes are much less effective at stabilizing a multi-joint, multi-axis system such as the spinal column, than stabilizing a single-joint system such as the elbow or knee. The application of the three-point scheme in a spinal support system, which includes a seat, has some advantage over a traditional spinal orthosis in that the most inferior force can be located at greater distance from the more superior forces to give a longer moment arm. However, the more the client functionally moves in his seated position, the less the seat is able to apply three-point support, because it doesn't move with the client. Furthermore, a spinal orthosis can be worn 23 hours per day, if necessary. These latter considerations make the spinal orthosis a stronger orthotic treatment of progressive spine deformity.

The second scheme we will discuss has to do with the Valsalva maneuver, given earlier, in which the abdominal and costal muscles function to relieve the spinal column of compression and bending loads. No matter what exactly happens during the Valsalva maneuver, the Morris explanation is a valid biomechanical analysis of how a snug corset contributes to trunk/spine stability in the presence of flaccid paralysis of abdominal and costal muscles. Engineering analysis and empirical evidence indicate that when we passively apply circumferential abdominal constraint (ie. a snug corset), a hydraulic load bearing column is created and we reduce the magnitude of flexible collapse (Figure 6). In our experience, the corset is seldom used for children with cerebral palsy, but is virtually always useful for children with muscular dystrophy.

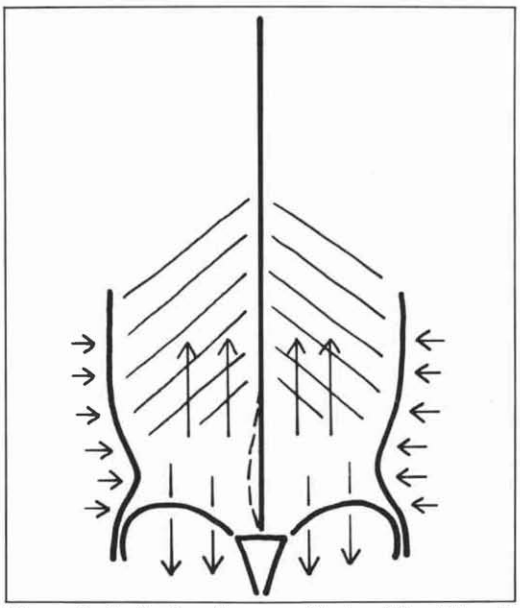


Figure 6. Reducing the magnitude of flexible collapse.

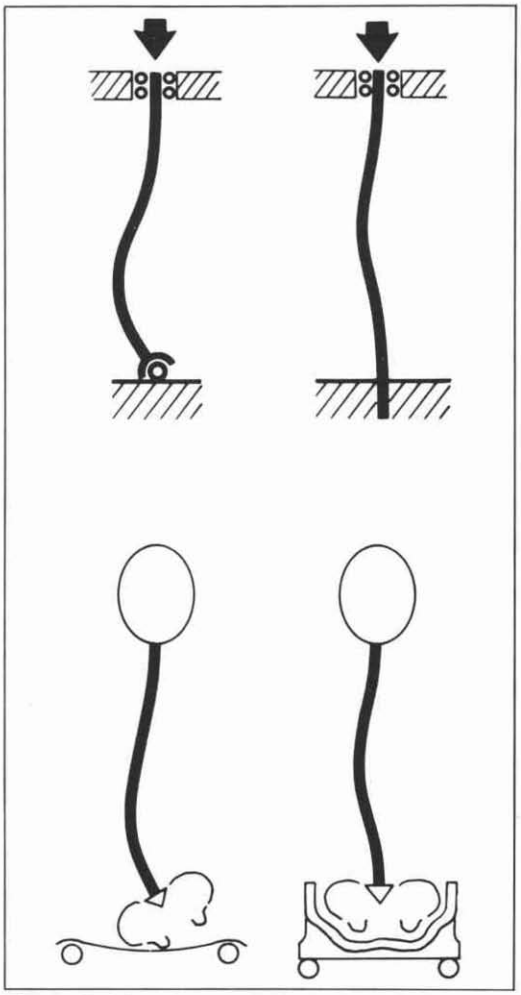


Figure 7. The diagrams on the left illustrate the similarity between the spinal column in the case of an uncontrolled pelvis and the slender column pin-jointed (free to tilt) at its lower end. The two diagrams on the right illustrate the similarity between the controlled pelvic case and the built-in base end condition.

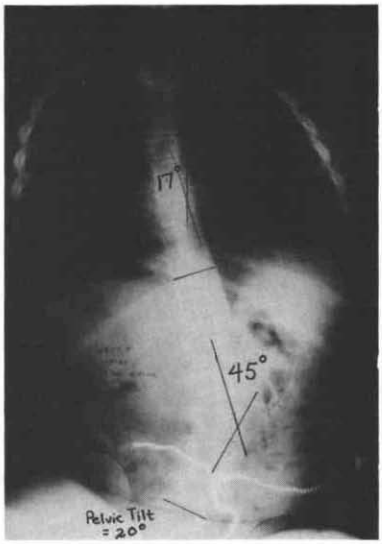
The third scheme for enhancing spine stability derives from the fact that the sacro-pelvic complex forms the foundation on which the flexible spinal column rests. Voluntary pelvic control is an important component of spine stability in the unimpaired trunk. If, by a conforming design about the pelvis and a proper donning procedure, we can increase the foundation (bottom end) constraint conditions, much is added to spinal stability. The pair of diagrams on the left side of Figure 7 illustrates the similarity between the spinal column in the case of an uncontrolled pelvis and the slender column pin jointed (free to tilt) at its lower end. The two diagrams on the right in Figure 7 illustrate the similarity between the controlled pelvic case and the built-in base end condition. Elastic column buckling equations for the two beams indicate that the built-in beam will withstand almost twice as much load as the other before buckling.[4] To achieve this end condition stability, we need a well made seat, as well as a procedure to level the pelvis each time the child is seated.

To fully appreciate the strength of this scheme in practice, compare the two x-rays in Figure 8. Figure 8a is the x-ray taken just before the pelvic leveling procedure was performed and Figure 8b is the x-ray taken a few minutes later, after the pelvic leveling procedure was performed. The Cobb angle is reduced from 36 degrees to 20 degrees by this quick procedure, which is normally performed as a routine part of positioning the child in the sitting support orthosis. These x-rays are of a boy with Duchenne Muscular Dystrophy; he was not wearing a corset.

A second example is given in Figure 9. The left and center x-rays show the progression which occurred in the eight months following fitting. During this period, the parents did not use the pelvic leveling procedure. The x-ray on the right was taken a short time after the center x-ray, with the only difference being the pelvic leveling procedure was performed before the last film. Note: once a spine deformity has become partially structural, the pelvis can be leveled only to the degree that the deformity is still flexible.

In summary, maintaining a level pelvis makes it easier to control the spine. Pelvic control and orientation in the frontal plane also relates strongly to the uniformity of pressures in weight bearing areas and minimizing the progressive deterioration of sitting comfort.

Let us now look at two examples were these stabilizing schemes have been simultaneously applied. Figure 10a is a photo of a 12 year old boy with muscular dystrophy, sitting as he was



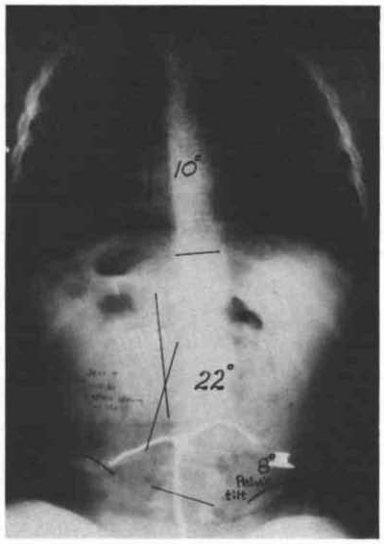


Figure 8a (*left*). **An x-ray taken just before the pelvic leveling procedure was performed.**

Figure 8b (*right*). **The x-ray taken a few minutes later after the procedure.**

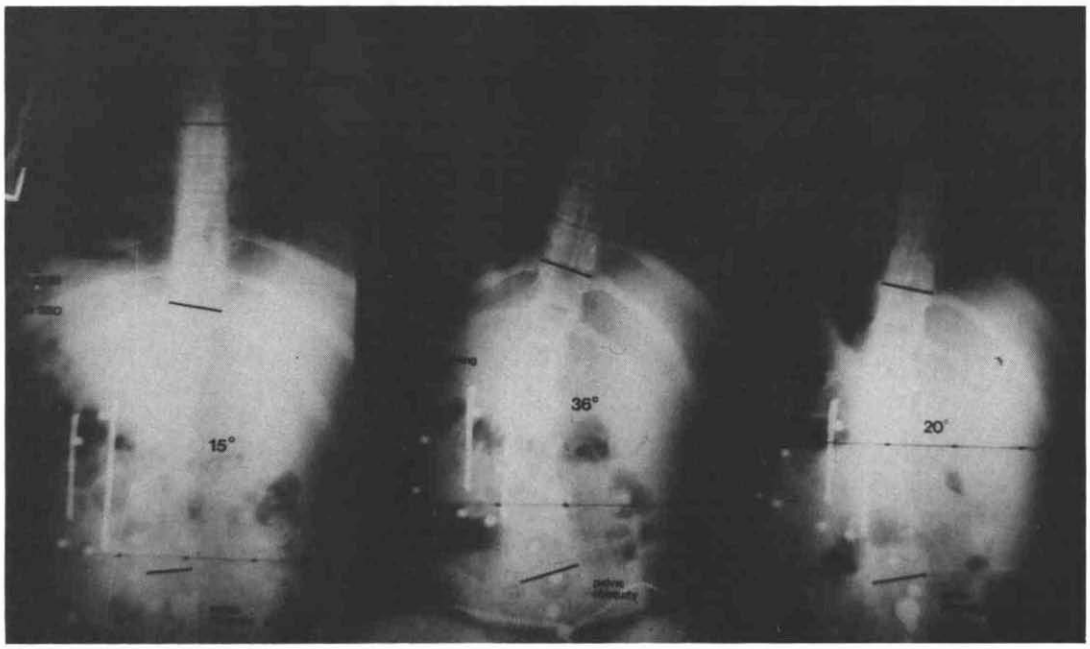


Figure 9. The left and center x-rays show the progression which occured in eight months following a fitting. During this period, the parents did not use the pelvic leveling procedure. The x-ray on the right was taken a short time after the center x-ray, and after the pelvic leveling procedure was performed.

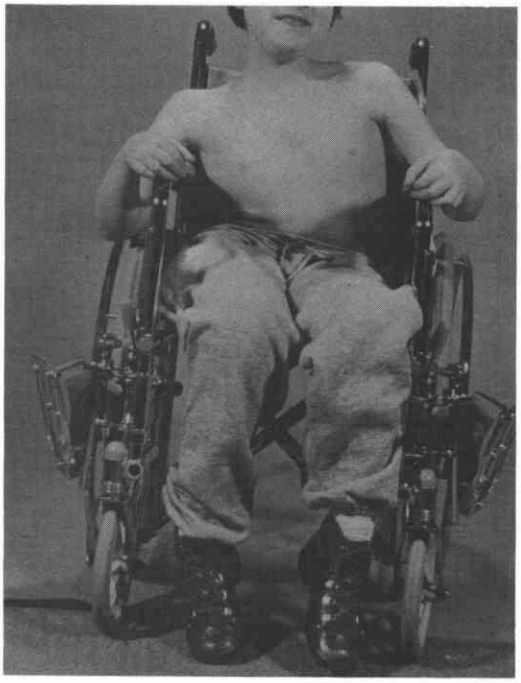


Figure 10a. A 12 year old boy with muscular dystrophy as presented.

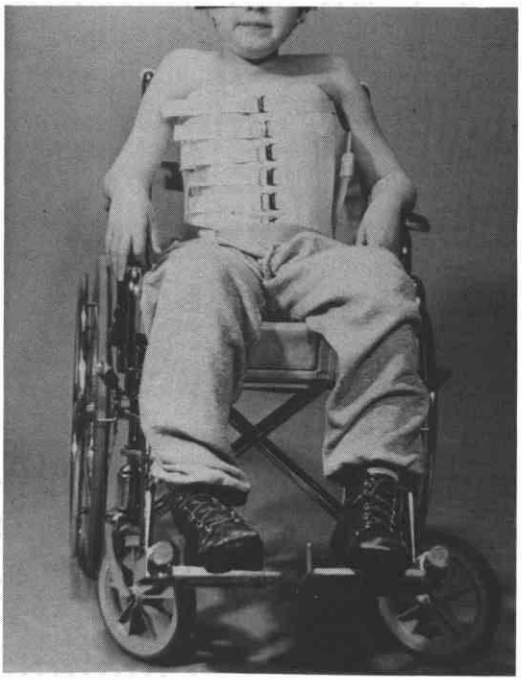


Figure 10b. The Sitting Support System properly applied. Corset is independent.

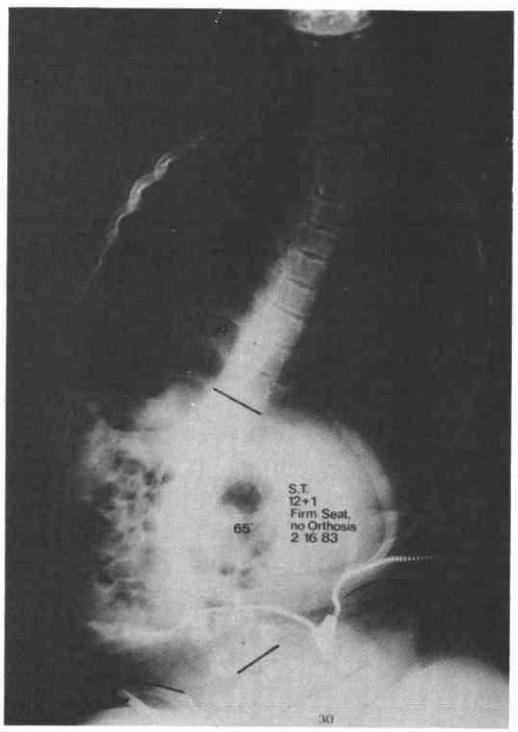


Figure 10c. A-P spine x-rays without the orthotic system.

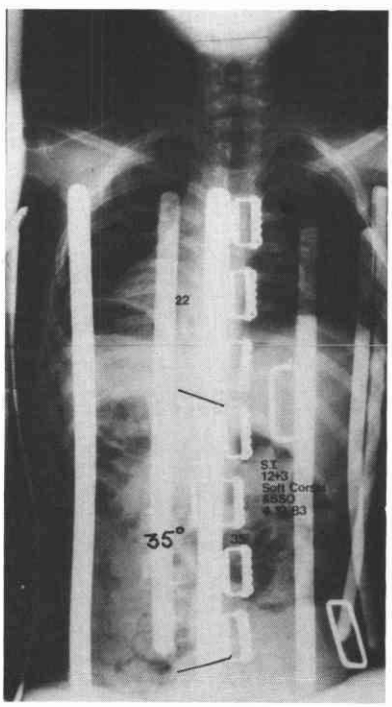


Figure 10d. A-P spine x-rays with the orthotic system.

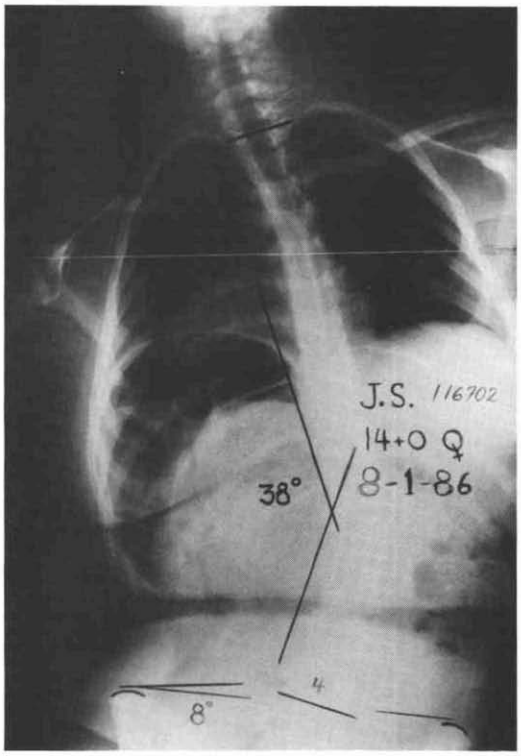


Figure 11a. X-ray of J.S., a 14 year old girl with cerebral palsy.

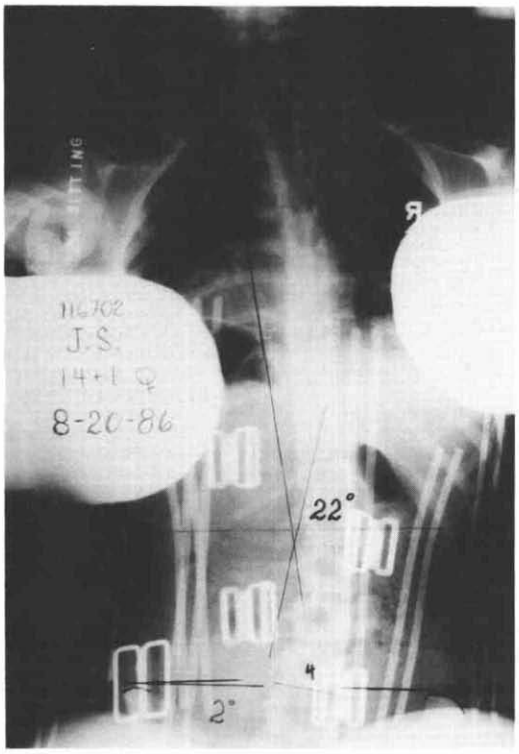


Figure 11b. J.S. provided with a soft corset and the Gillette Sitting Support Orthosis.

presented to us. Figure 10b shows the sitting support system properly applied. The corset is entirely independent; it is not attached to the seat. Figures 10c and 10d compare his A-P spine x-rays without and with the orthotic system. The lateral tilt of his pelvis is reduced from 30 degrees to 14 degrees. The Cobb angle of his scoliosis was reduced from 65 degrees to 35 degrees. Curve control of this magnitude is not unusual as long as the deformity is still flexible. Figure 11a is the x-ray of J.S., a 14 year old girl with cerebral palsy. She presented a right thoraco-lumbar scoliosis of 38 degrees and a rightward pelvic tilt of 8 degrees. Her shoulders were tilted 13 degrees to the left partly because she used her right arm for propping to avoid falling to the right. We provided her with a soft corset and the Gillette Sitting Support Orthosis. The Sitting Support Orthosis was to provide pelvic control and bilateral "propping" support. It had no head rest or anterior support. The x-ray taken just after fitting shows pelvic tilt reduced to 2 degrees (Figure 11b), the Cobb angle of the scoliosis reduced to 22 degrees, and shoulders leveled. Both hands were free to function, and she said she could breathe deeper.

In cerebral palsy, we occasionally see a case of lateral pelvic tilt and scoliotic posture secondary to a unilateral hip extension contracture. A right hip extension contracture, if not accommodated, will cause the right side of the pelvis to be elevated. The pelvis will be tilted leftward and a compensatory convex left scoliosis will be produced. When we see this problem, it is usually an older child or adult. Figure 12 is an example of a rather extreme case of how the deformity was accommodated to minimize pelvic and spinal malalignment and stress.

In the sagittal view, we commonly see a posture dominated by the powerful, very active hamstring muscle group. The gluteals are often helping to resist adequate hip flexion for an ideal sitting alignment. To a greater or lesser degree, the pelvis is maintained in a posterior tilt position with weight bearing shifted posteriorly toward the sacrum. This pelvic alignment tends to reduce lumbar lordosis and convert it

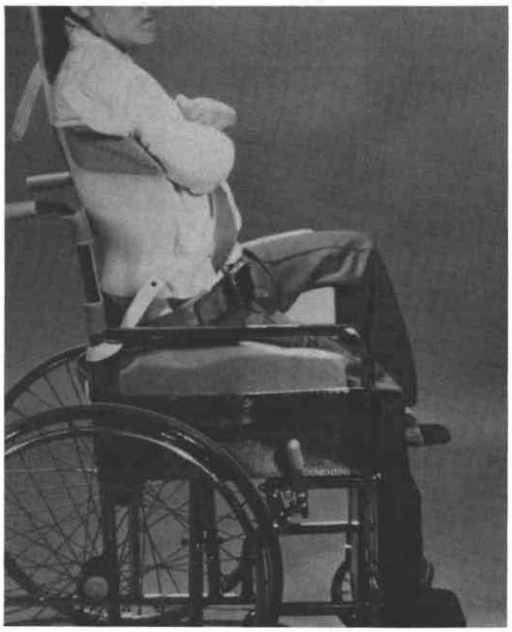


Figure 12. An extreme case of how pelvic and spinal malalignment and stress is minimized in a cerebral palsy patient.

Figure 13. A sagital view illustrating the pelvis in a posterior tilt position with weight bearing shifted posteriorly towards the sacrum, converting lumbar lordosis to a kyphosis.

to a kyphosis (Figure 13). The loss of lumbar lordosis makes it more difficult for the thoracic extensors to maintain a vertical upper thorax. This explains why a flexible spine, maintained with a pelvic belt and lumbar bolster to restore lumbar lordosis, often produces better active alignment of the upper thorax and head. (We would caution you that different solutions are necessary for people with rigid hyperkyphosis.)

The three forces needed to maintain the position of the pelvis and lumbar spine are the thigh support, lap belt constraint, and lumbar support (Figure 14). Attention must be given to properly provide all three. The seat bottoms must be configured specifically to provide optimum thigh support. A flat horizontal seat bottom will never maintain hip flexion against active extension (Figure 15). The anatomy itself calls for a depression under the pelvis to bring the femurs to a horizontal position (Figure 16). More importantly, the hip flexion required to "break through" the extensor spasticity varies from

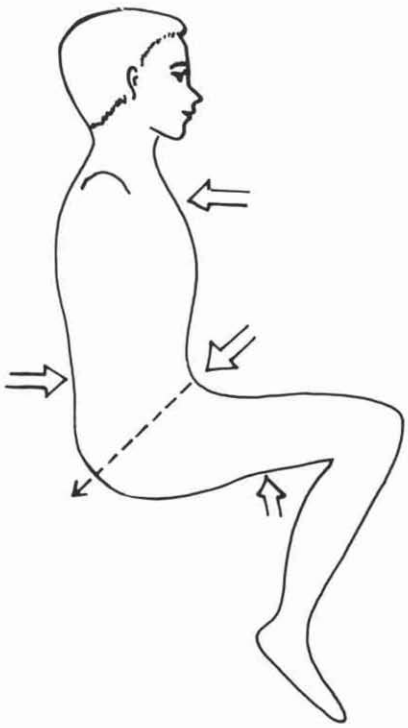


Figure 14. The three forces needed to maintain the position of the pelvis and lumbar spine are the thigh support, lap belt constraint, and lumbar support.

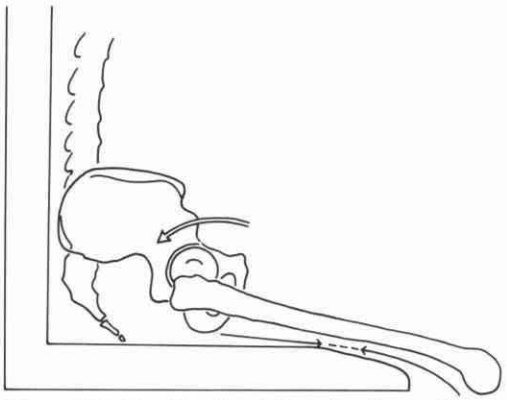


Figure 15. A flat horizontal seat bottom will never maintain hip flexion against active extension.

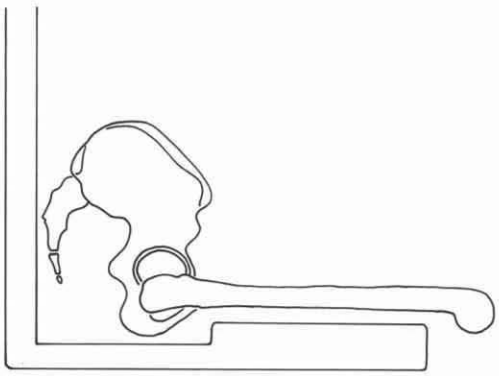
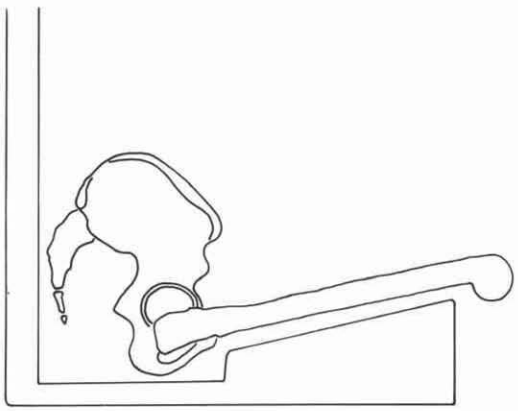
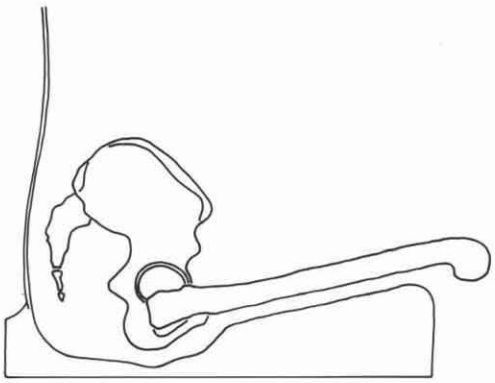


Figure 16. The anatomy calls for a depression under the pelvis to bring the femurs to a horizontal position.





Figures 17a and 17b. We usually find that some degree of seat bottom incline (pelvis to knees) is needed for more severely involved children.

child to child, but we usually find that some degree of seat bottom incline (pelvis to knees) is needed for the more severely involved children (Figures 17a and 17b).

The pelvic belt force is perhaps the most critical. The pelvic belt must be perfectly anchored: close to the body posterolaterally for good "wrap around" and at the correct level to achieve a good downward force component (Figures 18 and 19). The most common mistake is to anchor the lap belt too high. We have never seen one anchored too low. (We must remember that none of the hip/lumbar support forces function properly in service unless the caretakers know why and how to put the pelvis in position and snug up the pelvic belt. Without education and training of the users, our designs are worthless. We must train and retrain on every return visit.)

A fourth support force is sometimes needed in the area of the upper thorax or shoulders to maintain adequate thoracic extension. This is accomplished with a vest or shoulder straps which must be adjustable for grading the amount of support to fit the need, which may vary through the daily routine of activities.

Seating misalignment and deformity problems in the transverse plane are not uncommon among the severely involved cerebral palsy population. The problem consists of the pelvis being torqued right or left by deformities of one or both hips. A severe adduction con-

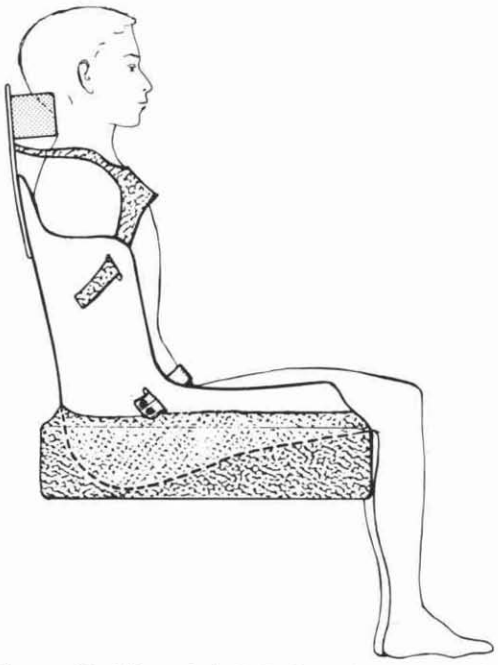


Figure 18. The pelvic belt force is perhaps the most critical.

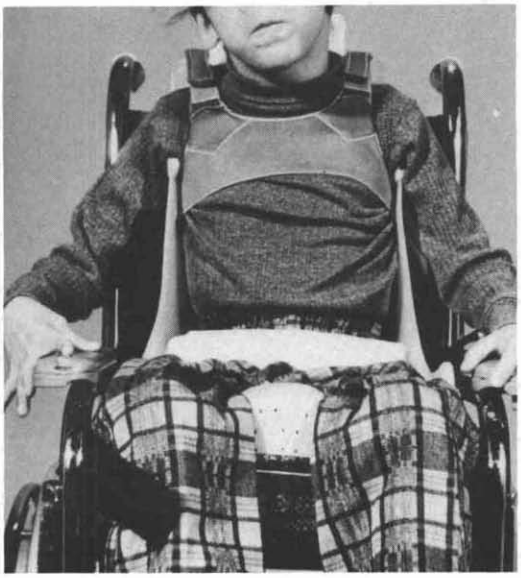


Figure 19. The pelvic belt must be perfectly anchored: close to the body posterolaterally for "good wrap around" and at the correct level to achieve a good downward force component.

tracture of the right hip will, for instance, cause a seated misalignment which includes leftward direction of the thighs (with respect to the pelvis), a rightwardly torqued pelvis, and an apparently (not actually) short right femur. This misalignment has been well diagrammed in an article by Mercer Rang, et al.[7] A severe abduction contracture of the left hip will cause a similar misalignment. These deformities are often referred to as "wind blown hips." We can see that when such a condition exists, forcing the thighs to be aligned straight forward will obligate the client to sit facing to one side, or the spine will be continuously twisted. In most cases, the direction of the thighs may be altered enough to avoid much of the spinal twist. Figure 20a is a photo of a top view of a Sitting Support Orthosis we provided for such a client. Figure 20b is the same view of the client in the orthosis.

It is of utmost importance, as we treat these clients, that we keep function and quality of life issues uppermost in our mind. Biomechanics and deformity prevention ideals often must be compromised to avoid undue impingement on any aspect of the child's development or function.

CLIENT EVALUATION

Seating evaluations at Gillette always include an orthotist, a therapist, and a physician in addition to the client, parents or caretakers, and, if available, a community therapist. The physical evaluation includes an assessment of orthopedic deformities, spastic reflex patterns, voluntary sitting capability, and other functional abilities. To assess sitting ability, two people manually control the child's thighs, pelvis and lower trunk. If, with this amount of stabilizing assistance, the child still cannot manage an upright sitting posture, we would grade voluntary sitting capability at non-existent to poor. If the child can, with that assistance, struggle to an upright sitting posture and maintain it for fifteen seconds, we would grade voluntary sitting capability at poor to fair. Better performance would be graded accordingly as better than fair.

A thorough interview of parents and others with the child is immensely valuable. We want to find out about the child's daily routine, mode of family transportation, what they feel are positive and negative features about their present equipment and routine, and the child's usual

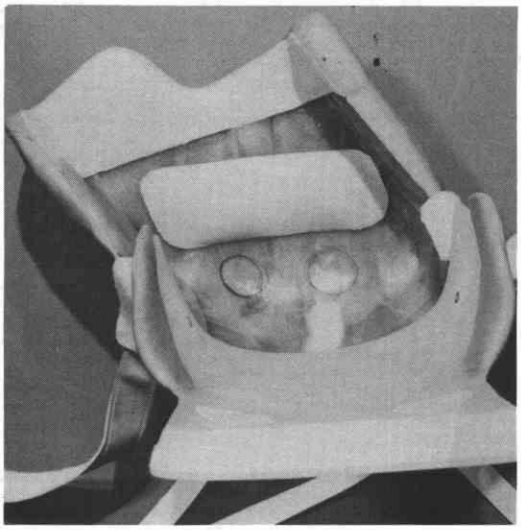


Figure 20a. Top view of a Sitting Support Orthosis.

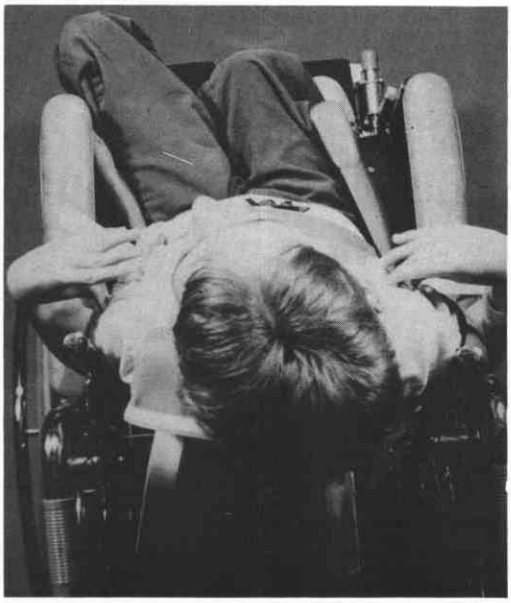


Figure 20b. A client seated in the S.S.O. The direction of the thighs is altered to avoid much of the spinal twist.

status compared to what we are observing. We also seek all concerns and ideas they may have for optimum seating. The interview should gradually become more of an educational session and finally a discussion of options. The child and parents or caretakers should, as much as possible, feel they were heard, were educated, and have participated in the decisions made on the seat, mobility base, accessories, etc.

SEATING DESIGN

We currently solve the majority of the seating problems we encounter with variations on two basic designs. Both are custom made.

Although there have been many very significant design changes along the way, the Gillette style Sitting Support Orthosis (S.S.O.) has continued, from 1974 to the present, as a portable system utilizing a custom molded unpadded plastic shell mounted in a plastic foam base (Figures 18 and 24). We have provided approximately 1100 of these Sitting Support Orthoses. Our present rate of S.S.O. production is about 140 per year.

In the early years, we also constructed upholstery and plywood seats. In 1983, we converted that rectangular design to one that used upholstered removeable components attached to the inside surfaces of a plastic seat frame as shown in Figure 21. (We first saw a design similar to Figure 21 at the Royal Ottawa Rehabilitation Center. In addition to our own changes, the present design incorporates features also learned from the Rehabilitation Engineering Center at Children's Hospital at Stanford.) To distinquish this design from the contoured plastic shell type S.S.O., we call it an Upholstered Sitting Support Orthosis (U.S.S.O.). We currently construct and fit about 200 of these units annually.

A more specific discussion of the design of the S.S.O. must start with noting that the main structure is an unpadded, thin plastic shell. Because of the thinness of the supporting shell, the seat is less bulky, less visible, and lighter than other seats. It allows us to provide close thoracic support up to the axillary level and wrap around the thorax, between the arms and chest, and well past mid-line, without impinging on the arms (Figures 18 and 19). When properly contoured, the shell can be left almost totally unpadded. The unpadded shell is easier to clean and requires less maintenance. The pelvic portion is contoured and sized to fit

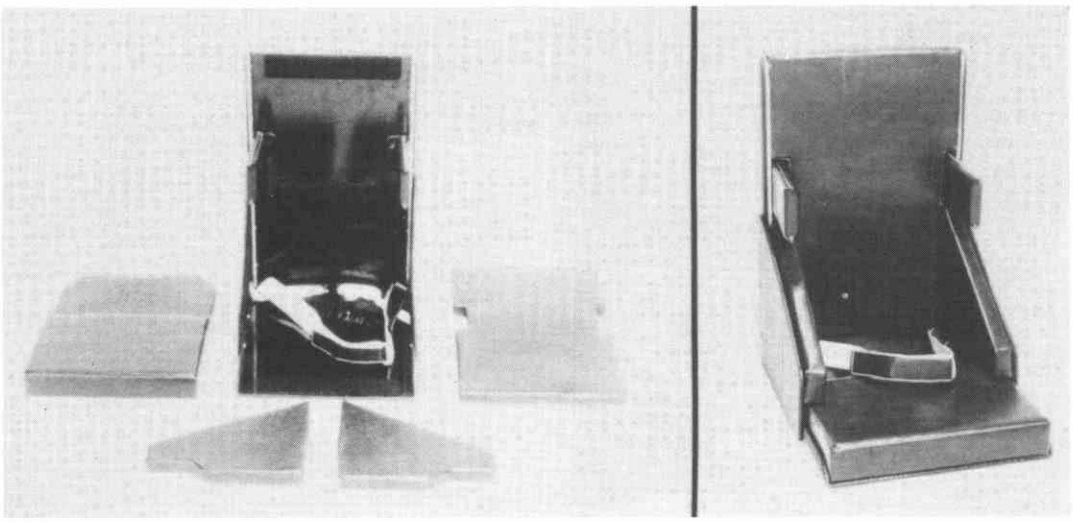


Figure 21. A plastic seat frame with upholstered removable components.

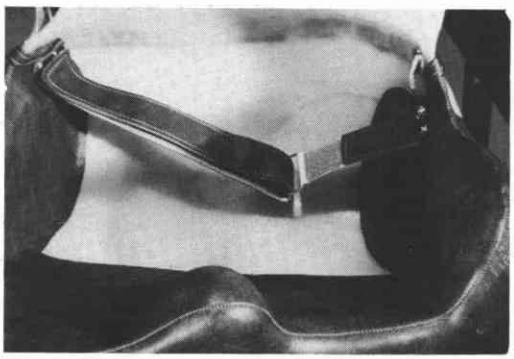
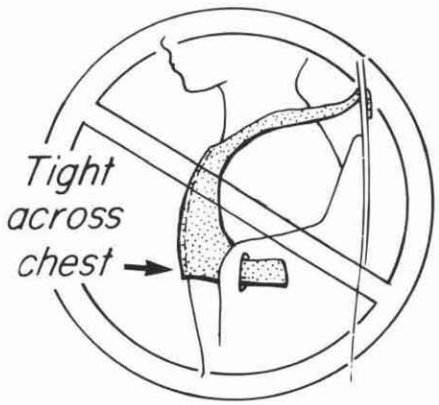


Figure 22. An unpadded shell with room to install bilateral pelvic growth pads, which are removable as the pelvis grows wider.

the hip/pelvic area quite close, but not snug. At fitting time, we leave adequate space to push our fingers between the Glueteus Medius and the seat bilaterally. About 18 months ago, we began providing room in the shell to install bilateral pelvic growth pads (visable in Figure 22), which are removed later as the pelvis grows wider.

Anterior upper thoracic support is provided by either a special vest (Figure 23) or shoulder straps (Figure 24). The shoulder straps are more efficient at keeping the thorax in an extended, upright posture. However, when the child has some arm function, we prefer to use the vest because it can be configured to impinge less on the anterior deltoid muscles. Note that the lower attachment points for the



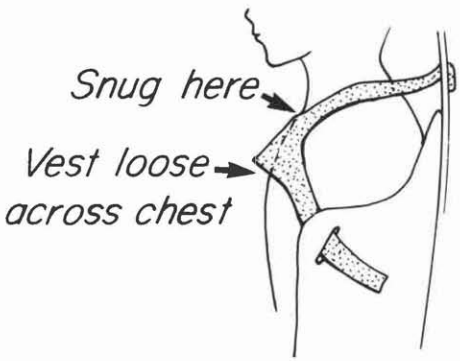


Figure 23. Anterior upper thoracic support is provided by a special vest or shoulder straps (see Figure 24).

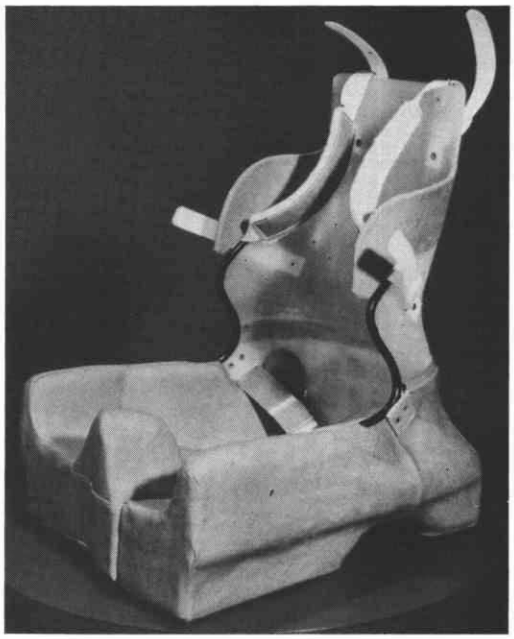


Figure 24. Anterior upper thoracic support provided by shoulder straps.

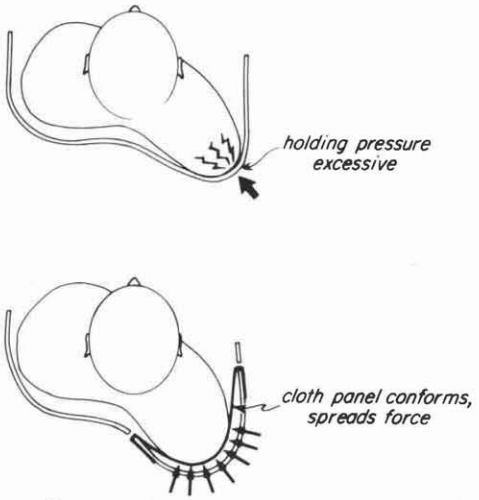


Figure 25. An adjustable denim cloth panel is installed through vertical slits in the shell. The panel wraps around the prominence, conforming to the contour.

Figure 26.

vest or shoulder straps should be in the sub-axillary area to provide good wrap-around and a posteriorly directed holding vector. Some commercially available seats anchor the shoulder straps to the lap belt. That design is seriously flawed because the shoulder straps then pull the lap belt up out of proper position and pull down on the shoulders.

When the S.S.O. is used for people with severe scoliosis or hyperkyphosis, the polypropylene shell accomodates to the contours of the deformity. However, sometimes our best efforts fail to create sufficiently precise contouring to spread pressure evenly over the entire rib prominence. Figure 25 diagrams how we sometimes solve that problem: an adjustable denim cloth panel is installed through vertical slits in the shell. The panel wraps around the prominence, conforming to the contour.

Head support varies from nothing to a simple occipital prop to a variety of designs, depending on the particular challenge presented. A few of the many designs we have contrived over the years are shown in Figures 26, 27, and 28. We do not have a good solution for the child who persists in actively bringing the head forward and down. In seating children with hydrocephalus, the sheer weight of the head presents special safety and weight bearing problems (Figures 29 and 30).

We haven't the space to show and explain the wide variety of accoutrements which are variously added for shoulder protraction, arm positioning, etc. We work closely with the therapists so that they can help design the final configuration for best functional positioning.

As emphasized earlier, a seating program must consider the sitting functional environment. The seating orthoses we produce are removeably mounted in wheelchairs, strollers, buggies, and other bases as the circumstances

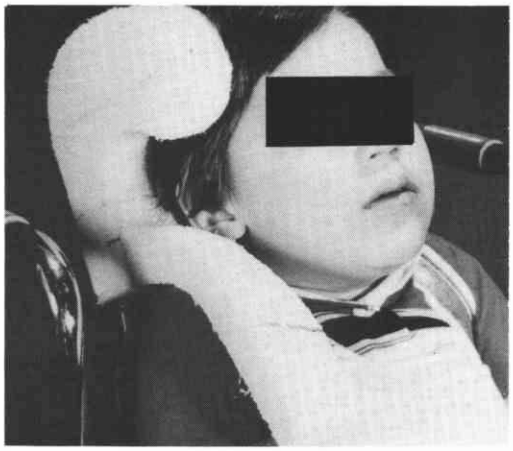


Figure 27.

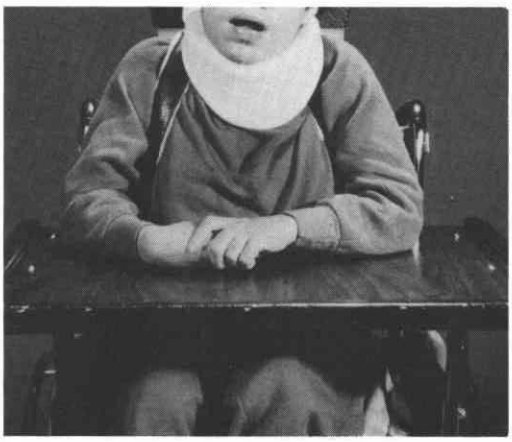


Figure 28.

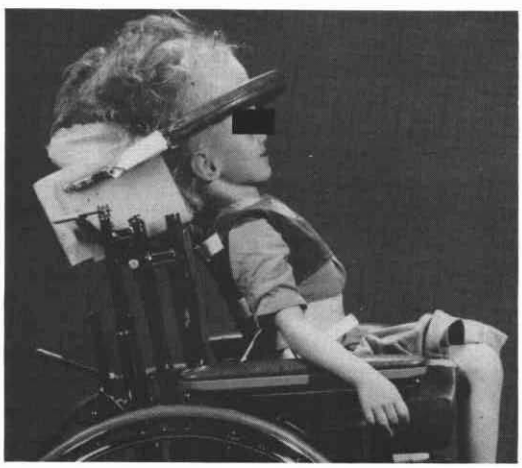


Figure 29.

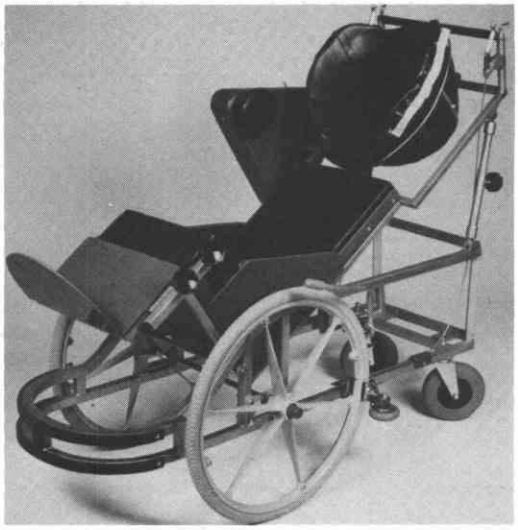


Figure 30.

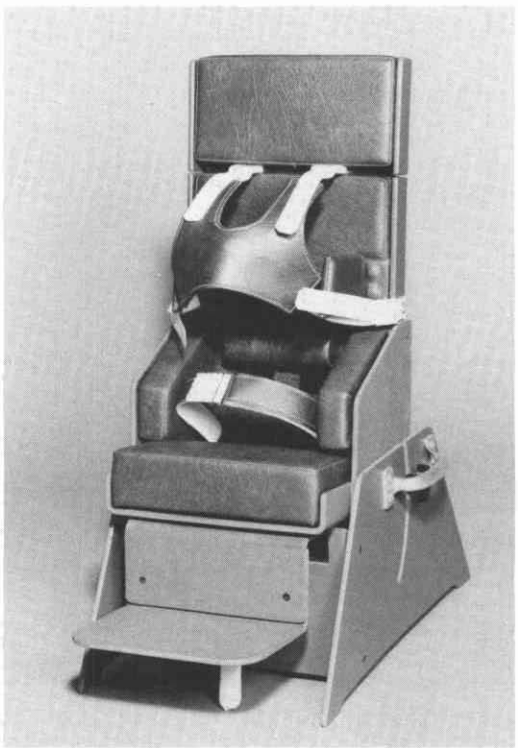


Figure 31. The seating orthoses we produce are removable and made to mount in a variety of bases as the circumstances indicate.

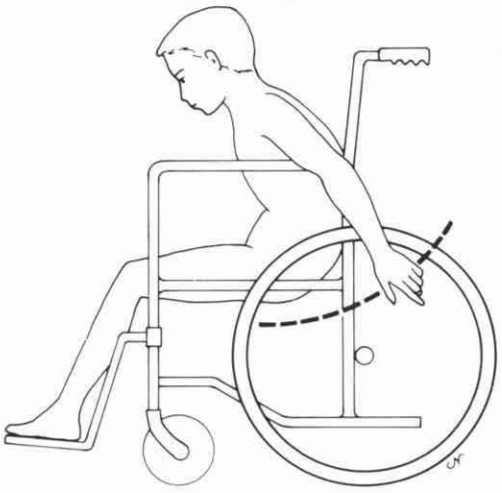


Figure 32. Lateral view of typical posture produced by hypotonic spine extensors and tight hamstrings.

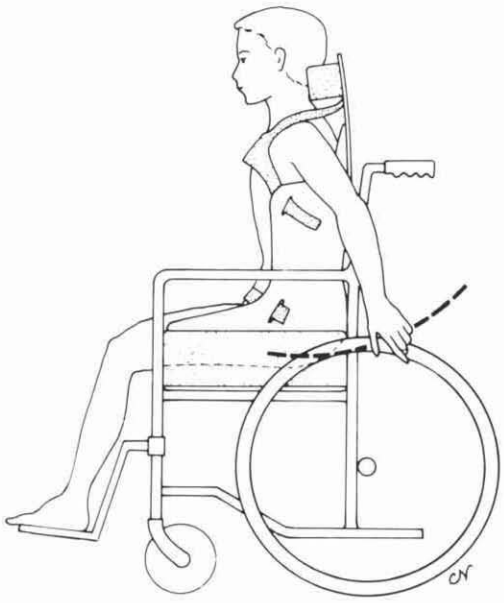


Figure 33. Lateral view of a patient positioned too high and forward.

indicate. Being portable, they are also utilized as car seats, or to place the child very near the floor to facilitate peer interaction (Figure 31). We have found that a seating program, to be effective, must address the full spectrum of life activities. It must also address related equipment in the sitting environment. Footrests, wheelchair upholstery, laptrays, and control boxes are some of the most common things which must be modified, moved, or completely replaced with special designs. It seems to us that the "standard" wheelchair was designed to be "slouched" into (Figure 32) rather than to be sat erect in. Those chairs are not adequate, as manufactured, for extended use by anyone. In spite of the newer, more enlightened designs coming along, those "standard" wheelchairs are still part of the scene and must be dealt with. When we sit a client erect on a firm seat, and then place that seat in a wheelchair, the client's shoulders are far from the center of the drive wheels (Figure 33). For clients who self-propel, the seat must be sized or shaped to sit between the upholstery mounting bars. The standard upholstry must be removed and replaced with straps so that the seat can be recessed down and back between the bars (Figures 34 and 35).

At semi-annual follow-up visits, we accommodate the child's growth by adjusting the size of the S.S.O. Thigh length is added as necessary. The bilateral pelvic growth pads are thinned or removed when appropriate. The back and sides of the shell can be heated to widen the shell width across the chest. Axillary extensions are welded on as necessary to accommodate increase in thoracic height. Head rests and the anchor points for vests and shoulder straps are also elevated as necessary. Presently, the basic S.S.O. shell is serving for an average of 37 months for children between 3 years and 14 years of age. We expect the use of the pelvic growth pads to push that service life even higher. For adults, the average useful life of S.S.O.'s is much greater.

We recommend the S.S.O. for children who have non-existent to poor voluntary sitting capability. Other factors which would indicate a need for the S.S.O., in our program, would be significant orthopedic deformities (of the hips and spine) and moderate to severe spastic reflex patterns. Completed physical growth may also be an indication for the S.S.O., because the polypropylene shell is very durable. It requires less repair maintenance than the upholstered systems. There is complete freedom within the design to reduce the level and amount of support or match the client's need: it may not in-

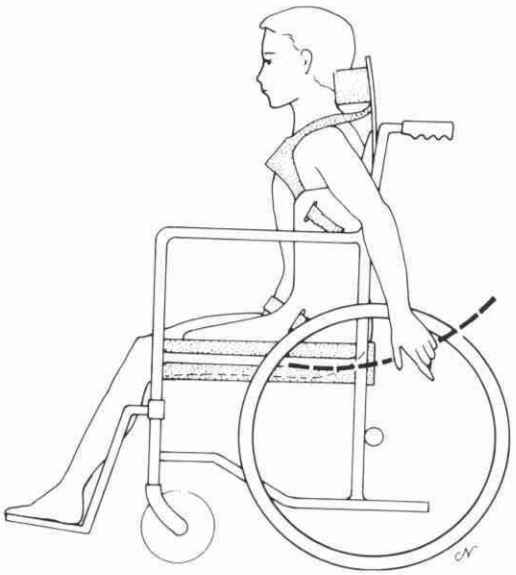


Figure 34. For clients who self-propel, the seat must be sized or shaped to sit between the upholstery mounting bars.

clude a head support, vest, or shoulder straps, and bilateral thoracic support may be terminated at a lower level and leave more room for movement as appropriate.

Provision of a good quality S.S.O. requires a relatively high level of specific orthotic skill and practice. This may be considered a disadvantage, but we feel the adaptability and quality which results more than justifies the necessary investment.

The structural components of the Upholstered Sitting Support Orthosis are made of ABS plastic. The upholstered firm inserts are removable to facilitate cleaning and adjustments for growth. Thoracic supports are thin (of metal) and can be easily adjusted to change height and spacing. The pelvic belt is used on every U.S.S.O. Lumbar bolsters, vests or shoulder straps, and head rests are used when appropriate. Figure 31 shows some of these design features. During therapy sessions, and for certain daily time periods, therapists or parents may wish to work specifically on improving upper trunk or head control. For this reason, shoulder straps and vests are designed for partial or complete loosening. Head rests can be easily removed from the unit (true of the S.S.O. as well as the U.S.S.O.).

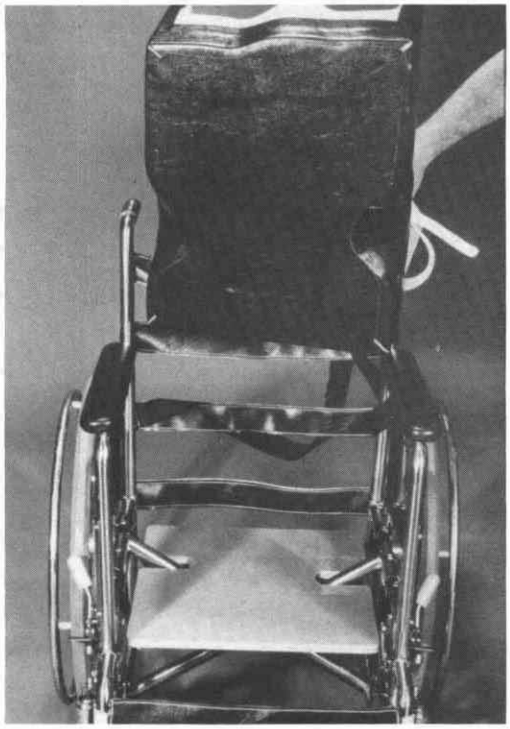


Figure 35. Standard upholstery is removed and replaced with straps so the seat can be recessed down and back between the bars.

The U.S.S.O. is most appropriate for children with poor-to-fair voluntary sitting capability, minimal orthopedic deformities, and less severe spastic reflex patterns. The easy size-adjustability of this design gives it some advantage over the S.S.O. for younger, rapidly growing children. For children under two years, we often utilize one of the commercial infant seat or car seat frames to which we can add support bolsters, lap belt, etc. (Figure 36).

FABRICATION

Much about the fabrication of these orthoses can be inferred from the photos and design information given earlier. Some information on fabrication of the "Gillette" S.S.O. has been discussed in earlier articles on that orthosis.[2,9] However, there are some serious errors in the S.S.O. fabrication process we made in the very beginning. Other orthotic labs might repeat those errors unless we reiterate a couple of the

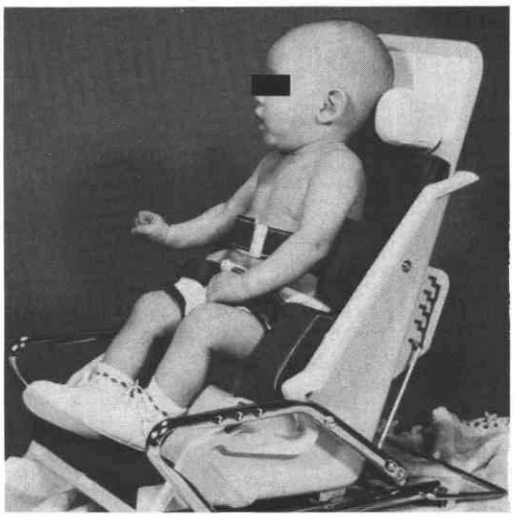


Figure 36. A commercial infant car seat can be supplemented with bolsters, lap belt, etc.

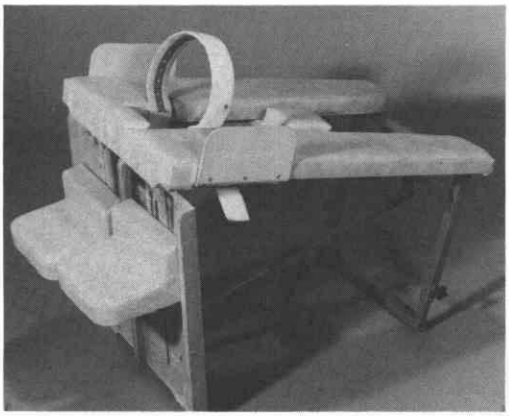


Figure 37. A supporting fixture.

procedural steps and more clearly explain the rationale for those steps.

The polypropylene shell is obtained by covering a pattern developed from an impression of the child. To obtain the impression, we position the child, on a supporting fixture (Figure 37) in a face-down, hips-flexed, knees-flexed configuration (Figure 38). We use the weight relieving (horizontal) trunk alignment, support under the knees, and a waist belt for the precise purpose of achieving an impression which does not possess the poor alignment characteristics we are trying to avoid. The support under the knees allows us to locate the pelvis as directly as possible in alignment with the spine. For the child with tight hamstring muscles, a waist belt on the fixture helps reduce lumbar kyphosis and perhaps achieve a little lumbar lordosis, if possible. The contrasting diagrams in Figures 39a and 39b illustrate the critical role of knee support. The hip flexion angle of the fixture can be varied and is adjusted according to the amount of hip flexion we want in the seat shell. On the positive model, plaster is added to create the bulges and contours needed to avoid pressure on bony prominences (Figure 40). Plaster is added across the back of the upper thorax to give room for extension. Figures 41a and 41b are posterior and lateral views of a positive model fully modified and ready for covering. The resulting polypropylene seat shell is

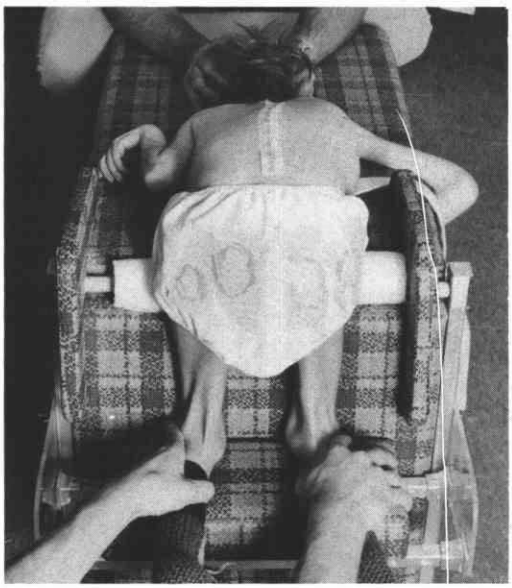


Figure 38. To obtain an impression for a polypropylene shell, the child is positioned face-down, hips-flexed, and knees flexed on a supporting fixture.

mounted in a polyethylene foam base (Figure 42). Final trim lines, lap belt and vest attachment points, head-rest placement, etc. wait until the child comes for fitting.

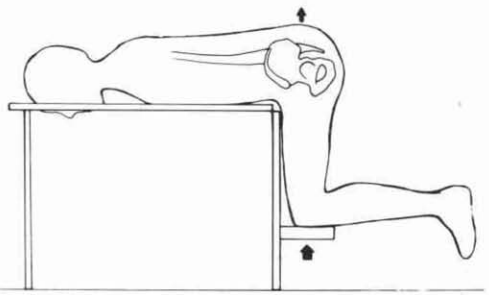


Figure 39a. Hip flexion angle of the fixture can be varied.

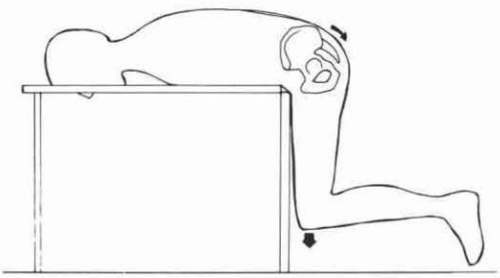


Figure 39b.

The molded "Chailey Heritage" supportive seat,[8] which also utilizes vacuum dilatancy to obtain an impression, creates a positive model, and vacuum forms the seat materials over that model. With the exception of those general similarities, the procedures, materials, and design of the Chailey Heritage seat is very different from the Sitting Support Othosis developed at Gillette Children's Hospital.

Fabrication of the U.S.S.O. does not require a pattern and is therefore free of the potential problems inherent in obtaining and modifying a model.

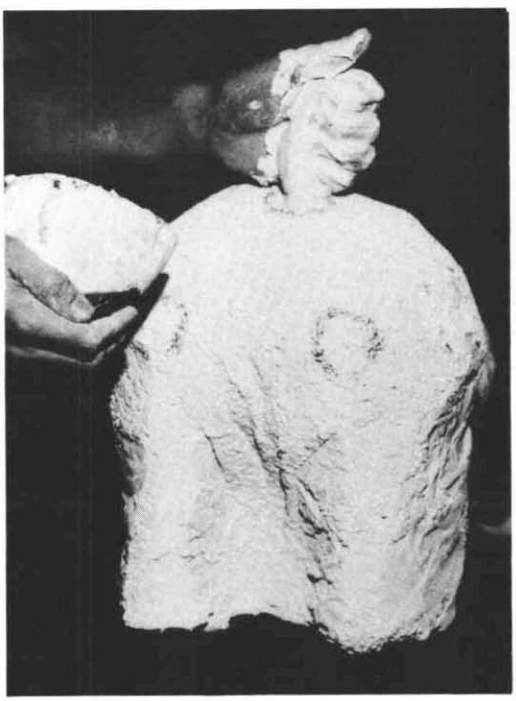


Figure 40. On the positive model, plaster is added to create the bulges and contours needed to avoid pressure on bony prominences.

CONCLUSIONS

This paper has dealt most heavily with biomechanics and design, but many other programmatic components have been mentioned. Devices do not solve seating problems. A program is required. A truly successful seating program, one that approaches the fundamental goals discussed at the beginning of this paper, must contain at least the following components:

1. Involvement of all appropiate and available professional disciplines.
2. Comprehensive discussion with, and education of, the client (when possible), the parents and/or other caretakers, and other available community-based professionals.
3. Attention to finding and solving the family-specific functional (including play, recreation, and transportation) problems and opportunities.
4. Provision of effective equipment with thorough instructions on its use.
5. Tenacious follow-up to uncover and solve the inevitable problems and opportunities brought on by growth and functional changes; to obtain feedback necessary to the efficient evolution of the program; and to reinforce, as necessary, the education of the users.

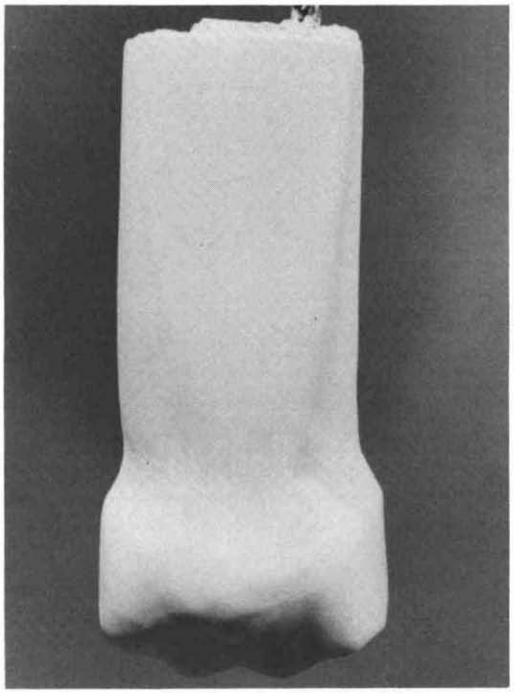


Figure 41a. Posterior view of a positive model fully modified and ready for covering.

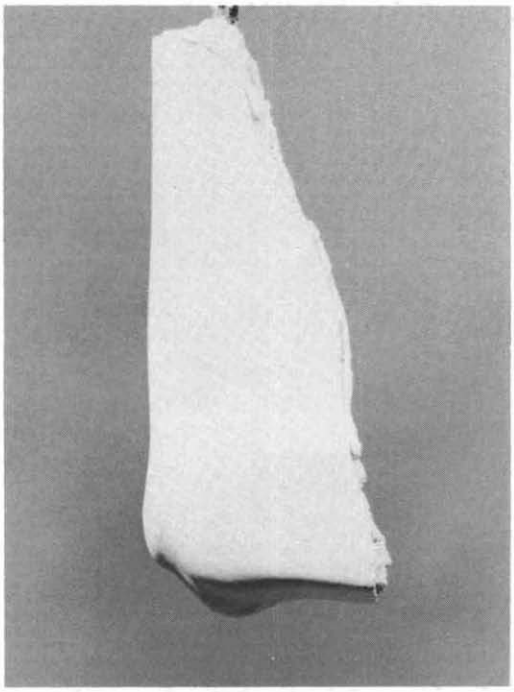


Figure 41b. Lateral view of a positive model fully modified and ready for covering.

ACKNOWLEDGMENTS

The important roles of some individuals and institutions have been cited earlier and will not be repeated here. Our experience with Duchenne Muscular Dystrophy has come primarily through Dr. Lowell (Hap) Lutter, chief of the Growth and Development Clinic at Gillette, and orthopedic surgeon for the Muscular Dystrophy Clinic at Fairview Hospital. The seating systems were provided at Gillette by Team Leaders, Mark Payette and David Wilkie, and the people they supervise. Those people include (currently, and in the recent past) Tracy Lillehaug, Joe Bieganek, Dannel Friel, John Spielman, Katie Voss, Lee Hegfors, Bruce Tew, Wendy Schifsky, Rick Weber, Paul Swanlund, Paul Lemke, and Marcia Munson. Gene Berglund is orthotic group manager at Gillette. Former Therapy Superivsors, Diane Twedt and Jan Headley were very involved and important during the early years of the program. Gillette therapists significantly involved with the program currently (or in the recent past) include Rebecca Lucas, Lynn Bowman-Bathke, Cindy Theisen, Patricia Mathie, Gail Graff, Marilyn Kochsiek, and Ellen Kratz.

Over the years, we have been privileged to work with many outstanding individuals and institutions in various communities in our referral area. Three institutions which have been especially cooperative and capable are the Cambridge Regional Human Services Center (formerly Cambridge State Hospital), People's Child Care Residence, Homeward Bound, Brainerd State Hospital, and Moose Lake State Hospital.

Figure 42. The polypropylene seat shell.

We have significantly learned from (in addition to centers cited earlier) the professionals associated with seating programs at the Rehabilitation Engineering Center of the University of Tennessee, the Hugh MacMillan Center in Toronto, and the Winnipeg Rehabilitation Center for Children.

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Commercial Options for Positioning the Client with Muscular Dystrophy

by Michael Silverman, C.O.

Before the advent of modern medicine, progressive weakening of the musculature was thought to be due to disorders of the nervous system. Early researchers thought the problem was with the nerves somehow being unable to activate the muscles, which in turn caused the muscles to atrophy. It wasn't until the late nineteenth century that researchers began to understand that these problems were due to the muscles only, without involvement of the nerves.

In 1861 Guillaume-Benjamin-Amant Duchenne, a Bolognese sea captain's son, published the first description of the severe childhood form of muscular dystrophy now known by his name. Specifically Duchenne noted that the disease ran in certain families, and he clearly defined pseudohypertrophy (false overdevelopment) of the calf muscles as one of the disease's symptoms. It was thirty years later that Wilhelm Erb described the underlying clinical features of the various forms of progressive muscular dystrophy and outlined four subvarieties. "Some of the observed features included symmetrical muscle wasting, progression, abnormal gait, a development of charcteristic body deformities. Erb was the first to see that these symptoms were disorders of muscle tissue, not of nerves, and he hazarded to guess that they were due to a complex nutritional disturbance."[1]

Over the last few decades, many categories of muscular dystrophies have been designated. Some, such as Myasthenia Gravis are controllable with simple medication, and do not require special devices other than lightweight orthoses. Others such as Duchenne muscular dystrophy, are progressive and require increasing amounts of specialized equipment to make the disability as manageable as possible. In this paper, the development of specialized seating for clients with muscular dystrophy, as well as new systems on the market today, which can help to make these clients remain as functional as possible for as long as possible, will be reviewed. Below are listed some of the major types of muscular dystrophy whose treatment will often require specialized seating.

Duchenne
(*Pseudohypertrophic*)

Rapid, ultimately involving all the voluntary muscles. Death usually occurs within 10–15 years of clinical onset.

Werding-Hoffmann
(*Infantile Spinal muscular atrophy*)

The earlier the onset, the more rapid the course. Respiratory failure and/or infection usually cause death.

Kugelberg-Welander
(*Juvenile spinal muscular atrophy*)

Variable, but usually very slow. Most patients live to old age.

Amyotrophis Lateral Sclerosis

Rapid, leading to death usually within three to five years.[2]

There are no easy rules for seating the client with muscular dystrophy. The pattern and severity of weakness varies from client to client,

and is usually changing so that each client has to be looked at for his individual needs. With the early onset of Werdnig-Hoffmann, specialized seating can be used to help with the prevention of deformities. These children tend to be very floppy. The positioning system will make them easier to handle and put them in a position where they can use their arms and hands to explore the world around them.

The pre-adolescent onset of Duchenne muscular dystrophy will often times lead to extreme curvatures of the spine unless the client is properly managed in a positioning system or orthosis. The advantage of using a positioning system in place of an orthosis is usually that of comfort. The positioning system should provide greater comfort to its user than the use of a wheelchair with a sling seat and back. The orthosis can be a source of discomfort to the user, and for this reason is likely to be left in the closet. "This tendency for the brace to be uncomfortable is understandable because of deformity is a collapsing type of scoliosis and the patient lacks the muscle power to pull away from a painful pressure area."[3] With degenerative forms of muscular disease, **the most important thing a positioning system can do for the client is to aid in increasing his function, allowing him to continue with normal activities of daily life for as long as possible.**

The client with Amyotrophis Lateral Sclerosis (ALS) presents a whole new set of problems for the clinician. Because of the age of onset and rapid progression of the disease, the clinician does not usually have to worry about the prevention of deformity. But these same problems make it nearly impossible to design a positioning system that will provide these clients with comfort and function for any reasonable length of time. Clients with ALS tend to prefer less contoured systems, and require adjustable reclining mechanisms for comfort.

Once the decision has been made that a positioning device may be beneficial, certain questions must be considered and information about the clients' family and home environment must be obtained. Then methods of transportation must be looked into. What is the prognosis of the clients condition? Is the client out with the family occasionally or most of the time? Are the outside conditions rural or urban? What are the client's favorite activities? What are the families needs? Does the family have, or will they be getting a van which would allow the client to be transported in his or her positioning system? How close is the roofline to the clients head while seated in their standard wheelchair? Is powered mobility needed now, or in the future?

An overall clinical evaluation should be made and the results of these tests should be available before any positioning decisions are made. A complete physical and functional evaluation of the client is necessary to determine the extent of the weakness and whether there are any contractures present. Orthopedic considerations add another dimension and may require the input of a surgeon to determine if releases are possible to aid in good long-term positioning. (A consideration with Duchenne muscular dystrophy is the question of a possible spinal fusion.) Any deformities which are present must be noted, as their severity will help further narrow the options for positioning the client. Slight flexion contractures of the hips or knees should not pose a problem for a successful positioning system. However, extension contractures of the hips or ankles could be more of a problem. Remember that a positioning system can serve a preventative role in reducing the formation of contractures and deformities, but the positioning system cannot be used to correct these situations. If correction is needed, it is best done on the operating table before the seating system is provided.

The seating system should allow the client enhanced abilities when using the system. The extremities also need to be looked at in relation to function. Arms must be free if independent mobility is possible; strength must be tested to determine if ultralight bases would be of benefit. The wheelchair is as much a part of the seating system as a headrest or foot support. There are many types of wheelchairs on the market today and the initial evaluation is critical in determining what type wheelchair would best serve the client. For the purposes of this paper, we will concentrate on positioning solutions only.

When deciding on the best position in which to seat a client with muscular dystrophy, it is necessary to start with the pelvis and achieve a neutral position to provide a stable base of support. Standard sling seats provide an unstable surface for sitting, as the pelvis will not sit

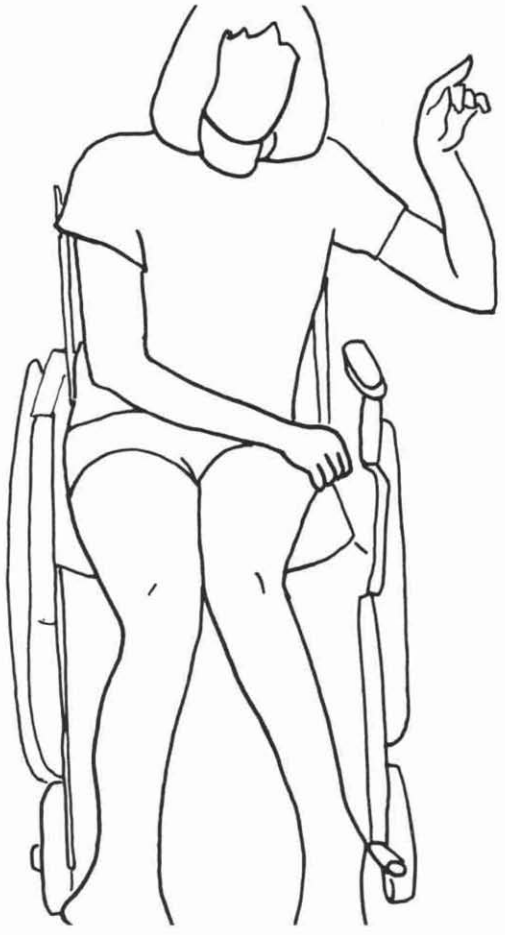

Figure 1. A person with abnormal tone becomes more a asymmetrical when seated on a hammock type surface. (A. Bergen and C. Colangelo, "Positioning the Client with CNS Deficits," 1985, p. 7)

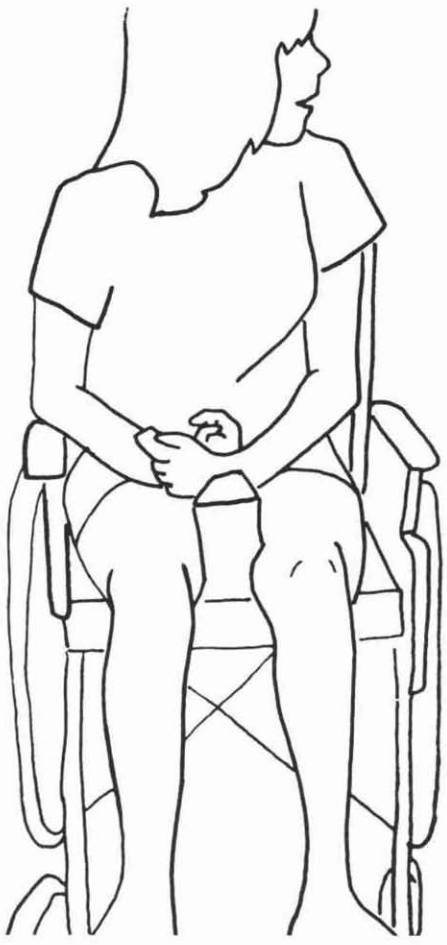

Figure 2. A firm sitting surface provides a base for symmetrical sitting. (A. Berger and C. Colangelo, "Positioning the Client with CNS Deficits," 1985, p. 7)

level and forces a lateral compensatory curve up the spine (Figure 1). The pelvis should be in midline and should not be allowed to slide laterally by blocks built into the positioning system. A 90 degree position of hip flexion is desired, and in some cases a back-to-seat angle of less than 90 degrees may be beneficial, especially when introducing increased lordosis into the spinal section. An anteriorly wedged seat will help to achieve a proper hip angle, while assisting to maintain the client in the seating system. The object is not to immobilize, but to stabilize the pelvis.

To complete the base of support for the upper body, the clinician must properly position the lower extremities. An abductor (wedge) will help to position the legs slightly apart giving a wider base of support (be careful not to bring the legs any wider apart than the diameter of the hips.) When using an abductor, keep it away from the groin and make sure it is of the flip-down or removable variety if a urinal is being used. Sometimes the clinician may wish to use an abductor as a reminder of the proper placement of the client in the positioning system, especially when there may be

multiple care givers. The knees and ankles should be at 90 degrees unless contractures are present. In many cases the knees may have to be extended slightly in order to clear the front casters of the wheelchair. The feet should always be supported so as to complete the stable positioning of the pelvis. As you can see, a great improvement in seating can be made just by replacing the sling seat upholstery with simple plywood and foam componentry (Figure 2).

Now the clinician is ready to work his way up the spine. The trunk must be held in midline, as close to natural shape as possible to allow better head control. In older clients the natural shape of the spine includes forward curves at the neck and lumbar region of the spine. For the floppy client, as well as those with a scoliotic deformity, lateral trunk supports are usually required. Usually with scoliosis, the pads are placed under the apex of the curve on the convex side, and under the axilla on the other side. The third point of the pressure system is the pelvic held in with good lateral positioners (Figure 3).[4]

With clients who have flexible spines, many different approaches to positioning are used. For the small child with spinal muscular atrophy, allowing the spine to shape into a gentle C-curve may promote the best head position. Increasing the lordosis with these clients may help to push them out of the chair, and cause their heads to fall backward. In the case of adolescent clients with Duchenne muscular dystrophy, increasing their lumbar spinal extension may actually help with the prevention of lateral curvature, as well as promote good head positioning. To understand this idea, one must first understand the mechanism of the spinal collapse in the client with Duchenne muscular dystrophy.

The first sign of spinal instability as demonstrated by roentgenograms (x-rays) is the appearance of a long thoracolumbar curve of less than 10 degrees sent in patients who are ambulating with the aid of long leg braces. During the early wheelchair bound stage, the curves lose their flexibility and they involve fewer vertebral segments, primarily in the lumbar spine, without axial rotation in curves of less than 20 degrees of lateral curvature as measured by Cobb's method. Rotation in the upper segment of the curve, which generally extends

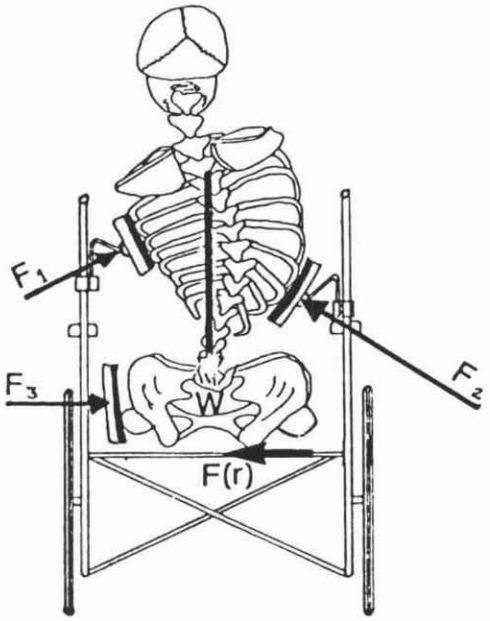

Figure 3. Transverse loading in seating the patient with scoliosis (rear view).

over the bodies of T10 to L3, is followed with maximal rotation at L2 of an estimated 5 degrees. Vertebral rotation then increases at a faster rate than the lateral displacement; and once rotation reaches 15 degrees and the lateral curve 30 degrees, both parameters increase rapidly.

Mr. Jan Koreska and his group at the Hospital for Sick Children in Toronto, Ontario have done many studies of the spine which suggest that if lateral displacement of the lumbar spine is not prevented, axial rotation follows, and by this time conservative bracing is unlikely to succeed since structural failure has already occurred.[5] They also found that the posterior facets and ligaments of the lumbar spine appear to be responsible for the linear alignment of the lumbar spine. The influence of the posterior facets on the upper lumbar spine appears to be less significant, because their resistance to axial rotation is reduced.

"Some 80 percent of the children develop a collapsing type of scoliosis." The observation of 62 spines of boys by the Hospital for Sick Children yielded consistent results. "A few patients' spines gradually became very stiff and somewhat hyperextended over a period of

years. When this happens, the patient will be a good sitter for a long time. The more usual pathway involves moving gradually from a straight spine, to a rapidly steady progression into a severe kyphoscoliotic."[6]

The first seating system developed specifically for prophylactic use by clients with Duchenne muscular dystrophy was developed in the mid 1970's. This specially designed seat was effective in limiting the progression of spinal curves to less than one degree per month in 13 out of 16 patients. The thought was, if spinal deformity could be maintained until skeletal maturity was achieved, good spinal alignment could be maintained. Clients whose curves progressed to greater than 35 degrees would usually ultimately require surgery.

The Toronto Spinal Support System (Figure 4) is made of a fiberglass shell, lined with custom carved ethafoam, upholstered with a modified urethane foam and a tricot double knit covering. Headrests, arm rests and leg supports are attached to the fiberglass shell. The unit is meant to be inclined backward a minimum of 15 degrees. The pelvis is snugly fitted and the thoracolumbar junction extended, while the back has lateral guides to promote midline sitting. "The snug fit gives the spinal column a stable base (the pelvis), and the extension of the thoracolumbar region reduces the mobility seen when the interarticular facet joints at this level are opened up in flexion. The 15 degree backward tilt reduces the load on the spine every time the patient leans back, while the foam lining makes it comfortable and acceptable to the patient."[7]

Conclusions from the group in Toronto over the last few years show that although spinal deformity is not absolutely prevented, development is slowed, prolonging the period of trouble free sitting. This slowing down of the development of the spinal deformity takes place at a time when spinal growth is rapid, making the introduction of the system at a young age before puberty of utmost importance. A 10 year follow-up to the development of the Spinal Support System (SSS) sponsored by the Muscular Dystrophy Association of Canada was completed in late 1983. Following are some of the more significant findings.

1. The Spinal Support System has made a significant contribution to the management of individuals with Duchenne muscular dystrophy across Canada. Improvement of user comfort is the attribute most consistently stated. The SSS development has been particularly well received by parents.
2. The SSS in its originally conceived design does not arrest the progression of spinal deformity. However, reduction in the rate of progression of deformity (1/3 to 1/2) was reported by the participating clinics.
3. From the clinical data available, it was not evident that any one single feature of the SSS is the key to the improvement of spinal management; but rather suggests that there is a combination of multiple interrelated factors involved.
4. There is no clear evidence supporting the hypothesis that extension of the lumbar spine is the key contributor to the lateral stabilization of the spine.
5. Lack of easy adjustment for growth or change of spinal alignment creates serious delays, or the postponement of the necessary revisions.
6. Although biomechanically advantageous, the 15 degree recline of the backrest necessitates that the child lean anteriorly

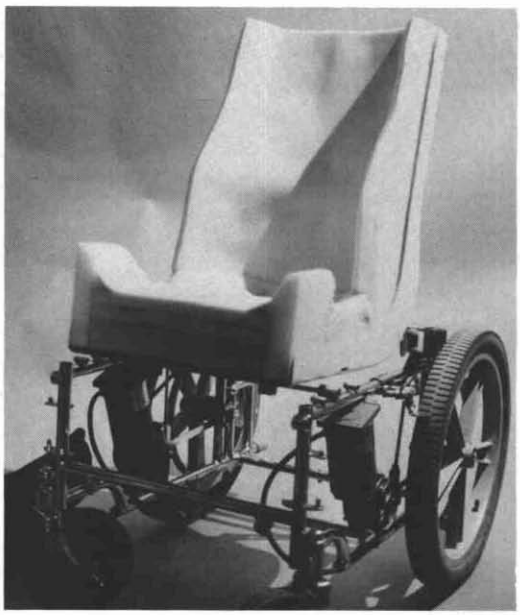

Figure 4. The Toronto Spinal Support System.

and away from the posterior supporting surfaces when participating in functional activities or seeking head stability. Only rarely were children observed or reported as using the back and head rest as intended by the designers.

7. The use of prefabricated modular components which results in relatively easy assembly is viewed as a very positive feature of the design concept.

The overall experience with the Spinal Support System was pretty well summed up in a follow-up study completed by a review committee in 1983. "Most of the principles obtained from the SSS study in Toronto have included the importance of the incorporation of a lumbar lordotic pad to maintain the lumbar and thoracic spine in a lordotic position. The concept is, if the spine is going to become fused, or rigid spontaneously, it will adopt a stiff extended alignment rather than collapsing kyphoscoliosis. However, this is the exception rather than the rule. There is no orthotic or seating system in use today, including the Spinal Support System, that will prevent the majority of these children (approximately 90 percent) from developing a collapsing kyphoscoliosis. Even in the few cases (perhaps 10 percent), in which the result is a stiff extended spine, the contribution of the seating system towards that outcome is probably only minimal. Surgery is serious; it must be offered to the patients and parents with full knowledge of potential complications. The patient's pulmonary reserve must be sufficient to withstand the surgery, and hence the disease. The rationale for surgical intervention may be difficult to accept by the parents when the effects of non-surgical intervention are not yet readily evident. If successful, the surgical intervention will stabilize the spine, making the seating problems easier for the management team. However, even when surgical stabilization is undertaken, appropriate seating systems are required, since the patient still requires pelvic support, upper and lower limb alignment and support, head support and mobility. Generally, the Spinal Support System has addressed the problem of development of scoliosis in muscular dystrophy patients. It has decreased the rate of progression, as shown in several studies. However, this may be detrimental to the patients general health because of the progression of the decreased pulmonary reserves. That is, the management team may be lulled into a "wait and see mode," only to find out later that the reduced vital capacities have shifted the balance of risk towards non-surgical management, whereas early surgical intervention would have been the treatment of preference. The use of the modified Spinal Support System in conjunction with early surgical stabilization of the spine may be useful.[8]

The Spinal Support System was a pioneering development at a time when there were virtually no commercially available seating systems or components. Today, the interest in specialized seating is booming, and commitment by manufacturers has led to a variety of systems and components. In this next section, some of the newer systems on the market and how they are used as tools for positioning different types of clients will be reviewed. Also, current methods of seating and their ability to correct a corresponding level of orthopedic deformity will be considered.

In a case where there is no orthopedic deformity, or very little orthopedic deformity which does not present positioning problems, the standard wheelchair should still be modified with a rigid seat insert, or off the shelf wheelchair cushion over a rigid base. The normal folding wheelchair with a sling seat and back does not provide a stable base of support for the pelvis. It is alright when used temporarily, but if it is to be used for any length of time, a firm seat insert is mandatory. Sitting on a sling seat causes the hips to internally rotate, contributes to abduction and usually an oblique pelvis, which in turn causes a compensatory spinal curve. The client with muscular dystrophy will have differential muscle weakening in the spinal musculature, and will almost always assume this position in due time. Therefore, for anyone sitting in a wheelchair for more than just quick trips, the addition of a rigid seat is mandatory.

Most wheelchairs can be ordered from the factory with a rigid seat of either the drop-hook variety, or attached with a special folding mechanism. A firm seat can also be made as a separate piece meant to be placed on an existing wheelchair seat. Those wheelchairs with attached non-removable rigid seats tend to make the folded chair unruly and increase the weight. The separate variety is preferred, but

because it is removable, it is often left behind. This problem is usually alievated with the drop-hook seat. After removing the seat upholstery, these cushions have special hooks which clip on to the seat rails with clamps. (The wheelchair then can not be used if the seat is left behind.)

The base of the seat cushion is usually plywood, at least 3/8". On top of the wood, different foams can be used, preferably a high density urethane which will not bottom out over time. In Chicago, we make three or four-inch cushions of two different types of T-foam or Sun-Mate foam which have special weight distribution properties. On the first layer, we use one to two inches of firm Sun-Mate for the base and two inches of medium-to-soft foam on top of that. The cushions are then upholstered with a thin flexible vinyl surface. The vinyl takes away some of the properties of the Sun-Mate foam, but protects the open cell structure against water damage.

Where problems with either boney prominences or an already oblique pelvis are envisioned, the Jay Cushion will provide a stable surface while accommodating these deformities. The Roho cushion provides excellent pressure relief, but may not provide enough stability and encourage leaning. The Roho is best used where pressure relief is the main concern and stability is not a problem, as with paraplegics. This is why an overall clinical evaluation is important as well as an understanding of available products. There are many other commercially available seating cushions on the market, and they must be in stock and tried on the client to determine if one will better fit the clients needs than another. A good place to see all of what is commercially available in this field is at the National Home Health Care Expo in Atlanta.[9] The show is always in late fall or early winter and is free.

For the moderately involved clients with muscular dystrophy, there are also many choices available. More likely they are the type of clients seen. These clients spend almost all of their time in a wheelchair when not in bed, and are in the early to moderate stages of deformity or contracture. Moderate levels of deformity or contractures are measureable, but not enough to create seating or functional problems.

The most widely used method of manufacture for seating devices today is using plywood and foam technology. Here there is a seat and back section, with body supports, pelvic supports, and leg supports bolted on. Many clinicians combine the linear plywood technology with custom carving of blocks of foam (usually ethafoam) to give a custom contoured look. The advantage of the contoured system is that they provide a larger area of contact between the seating system and the client. The Toronto Spinal Support System mentioned earlier is just an advanced version of this method, utilizing component parts such as a preshaped fiberglass shell instead of plywood. It was also one of the first systems to have head rests, arm rests and leg supports specially designed as part of the seating system.

Today it really makes little sense to make an entire seating system from scratch with so many commercially available components on the market. Many companies will actually make the entire seating system based on measurements of the individual client. For componentry and/or complete systems of the non-molded variety, some of the leading systems include those manufactured by Scott Therapeutics, Freedom Designs, Miller's, CRD, Gunnell, and CP seat by Pin Dot Products. Of the contoured modular systems, there is the Winnipeg system, the Otto Bock MOSS System (Figure 5) and the Pin Dot Modular Seating System (Figure 6).

These systems are all designed for "moderately involved" clients who have minimal deformities only, with no rotational deformities. Rotational deformities become more and more evident as lateral deformities increase, and the linear systems (or those contoured with preformed cushions) becomes less and less effective.

The next group with rotational as well as lateral deformities are designated the high moderates or low severe. Two new systems developed recently by the University of Tennessee Rehabilitation Engineering Program work well for this category. The Foam-in-Place seating system (Figure 7) uses a plastic module with an elastic bladder which fits into the chair, and liquid polyurethane foam is measured, mixed and injected into the empty bladder while the client is properly positioned on a pre-ischial strap. The foam rises and within minutes sets up and forms a customized seat or back

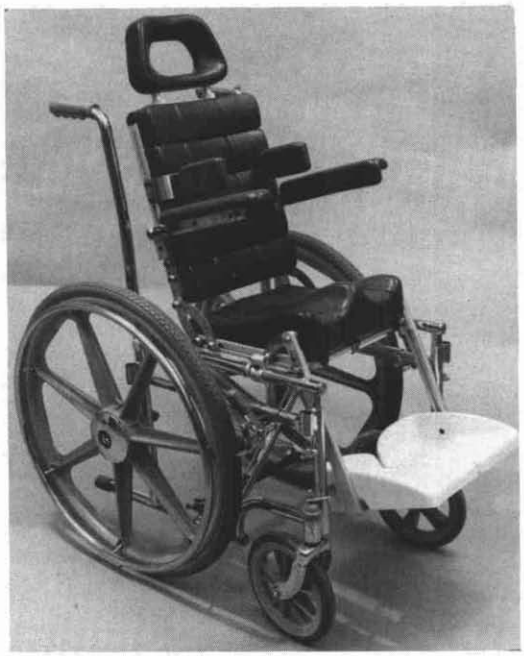

Figure 5. The M.O.S.S. system from Otto Bock.

cushion. Because the foam takes on the exact contours of the individual, it is possible to accommodate difficult rotational deformities. The difficulties with this system are that the client is forced to sit on a 2 inch wide strap, and be perfectly positioned in a chair while the foam is mixed, injected and set up (about 5 minutes). Even though the foam can shape to the most severely involved, only the high moderates can support themselves or be supported in the proper position under these conditions. Foam-in-Place may be better used for seat cushions only, as they are easier to form and more consistent in their results.

It is important to remember that all of the systems described here should not be thought of as complete systems only, but also as various components. The best way to produce an individualized seating system is to use some of the various components of each system in the best way possible to give the desired result for the individual client. Adrienne Bergen, O.T.R., a pioneer in this field, has used the word "eclectic" to describe those devices made from a variety of components from various companies, and it allows her to best fill her clients needs in the most economical manner.

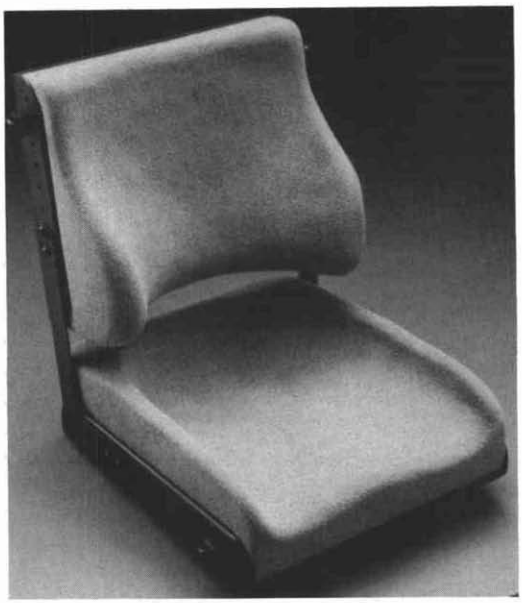

Figure 6. Pin Dot Modular seating system.

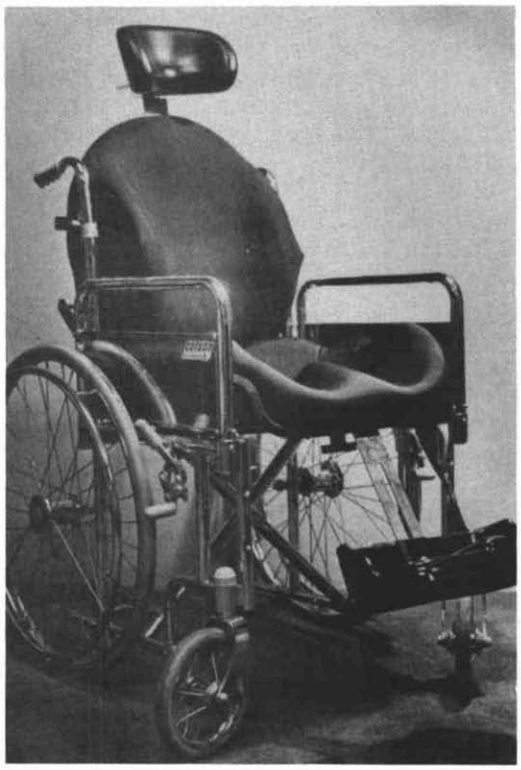

Figure 7. Foam-In-Place seating system.

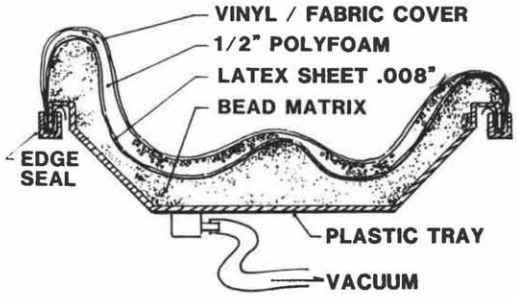

Figure 8. Side view of Bead Seat Technology.

The Bead Seat is another new development from Douglas Hobson's group at The University of Tennessee Rehabilitation Engineering Program, which uses essentially the same componentry of the Foam-in-Place seating system. The difference between the two systems is the filling or "stuffing" in the cushions. In the Foam-in-Place system there is a liquid foam which sets up and forms while the person is suspended over the empty shell. The Bead Seat's "stuffing" is a mixture of a fast setting epoxy and polystyrene pellets (Figure 8). The epoxy will set up two hours after the introduction of the catalyst, locking the lightweight pellets into the form desired. The form is made while the whole system is under vacuum using the dilation method.

Dilation is a molding technique used for more than three decades, and consists of an airtight bag filled with pellets and attached to a vacuum pump. When the vacuum is introduced into the system, the bag compresses against the pellets and holds whatever shape it has prior to the introduction of the vacuum. To change the shape, air is introduced into the bag, loosening the pellets' structure and allowing a change in shape.

The Bead Seat system depends on the vacuum to hold the shape until the epoxy sets up, creating a mechanical bond between the styrene pellets. Once the epoxy has set, the vacuum can be removed and the positioning system completed. The advantage of the Bead Seat over Foam-in-Place is that there is more time available to mold and remold the system, while simulating the finished system, to attain the desired shape. The extra time available for shaping with the Bead Seat allows it to be used with more severely involved clients than Foam-in-Place. This advantage of extra time is also a disadvantage when compared to the Foam-in-Place system, since it takes longer to produce the finished product. Also, when finished, the Bead Seat has a harder surface compared to the flexible surface of the Foam-in-Place cushion. This harder surface may be an advantage with positioning, but a disadvantage when pressure relief is the objective. Bead Seat, as well as Foam-in-Place, will accommodate rotational deformities, but may not be durable enough for the long-term needs of the larger clients because of the plastic framework. For lighter clients (under 100 pounds), the Bead Seat will easily accommodate the severely involved. Another limiting factor of both the Foam-in-Place and Bead Seat systems is that only a headrest system and a simple 90 degree legrest are available as options for customizing the systems, as they are designed to be used with the accessories in the existing wheelchair and this may not be enough for the most severely involved clients.

When dealing with the severely involved, the traditional orthotic approach is the vacuum-formed plastic or Gillette style seating system. Using this system, a mold is taken of the individual by placing the client, prone on a table with the hips flexed to 90 degrees, while a mold is taken using either the dilation method or with plaster bandages. This method of taking an impression is a problem. The mold (or measurements) should always be taken while the client is simulating the final seating position. The effect of gravity on the client cannot be felt when the client is molded in a prone position, and the client's shape may be completely different when upright. It is easy to straighten a client's spine when prone on a table; the problem is that the client may not be able to tolerate this corrected position for long periods of time when upright. This applies especially to the client with muscular dystrophy, who may not have the muscle strength to pull away from a sore area. When one is dealing with a client in the severely involved category, the idea is to correct as much flexible deformity as possible, while making the positioning system as comfortable as possible so the client will be able to use the system for long periods of time during the day.

Other difficulties with the traditional orthotic approach include the time needed to fabricate the finished system and the inability to adjust the system once it is finished. These problems are the same as those encountered when making a sophisticated seating system out of plywood and foam. With the traditional orthotic approach, the finished mold is filled, smoothed and corrected. Over the finished mold, a layer of foam is vacuum formed, then a layer of polypropylene is added. The plastic shell is then trimmed out, set in a box to form a base so it sits in the wheelchair at the desired angle, and upholstered. Time is valuable, and today most private facilities cannot profitably produce seating systems in this manner.

Today, because of the large amount of commercially available componentry, systems do not have to be made this way. Is anybody still hand forging knee joints? Today seating is where orthotics was in the late 50's or early 60's, at the advent of commercially available componentry.

Two newly developed systems work especially well for the severely involved clients; the Contour-U seating system (Figure 9) and the Matrix seating system. Contour-U utilizes the same dilation technology as the Bead Seat, but molds are taken on a specially designed molding frame with rubber seat and back bags filled with polyethylene pellets. Once a mold is taken of the individual in the proper position, plaster splints are worked into the mold to give a positive impression of the client. The molds are then turned into flexible upholstered cushions on a central fabrication basis, designed to eliminate the shop time needed for fabrication. The finished seat and back cushions snap into aluminum hardware, which also has the ability to be angularly positioned (both back-to-seat angle and recline orientation), and adjusted for length. This system accepts a wide variety of accessories designed to accommodate even the most severely involved client properly. The system is not labor intensive, but can be expensive, especially when used with the many accessories available.

As clinicians, knowledge of patient priorities should be uppermost. Don't use Contour-U when a Bead Seat will do. Don't use a Bead Seat where a Jay cushion will do the job. Think eclectically for the patient. Contour-U cushions with plywood and simple componentry can be used to create an inexpensive, custom molded seating system. For another client, a Bead Seat molded back and a Foam-in-Place seat may be the best solution.

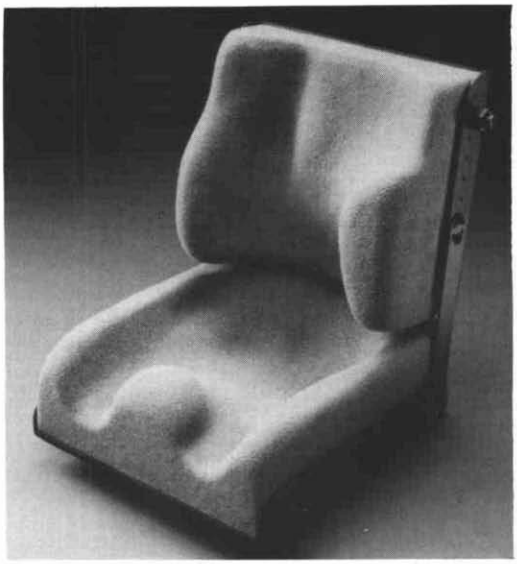

Figure 9. Contour-U seating system.

Another advancement in seating developed in Vancouver and now manufactured in England is the Matrix system (Figure 10). The Matrix takes an altogether different approach by providing a flat sheet of locking ball joints which can be contoured to almost any shape and locked into that position by individually tightening the ball joints.

Essentially, a sheet of material into which tucks can be taken and contours formed, Matrix can be fabricated to position somebody in any position desired. A nice feature of the Matrix is that it can be loosened and reshaped when necessary. Also, where growth is expected, the matrix can be extended by just adding a row or two of modules. The disadvantage of this system is in the time required to produce the finished product. Anywhere from 15 to 25 hours is necessary, which puts it into the same category as traditional orthotic seating systems. Fortunately, Matrix fabrication is also available on a central fabrication basis.

Some may consider the Matrix unattractive, but its high tech design also makes it airy, lightweight, and waterproof. The Matrix fits in well with the eclectic approach, as pieces of the material may be used for a custom head rest or

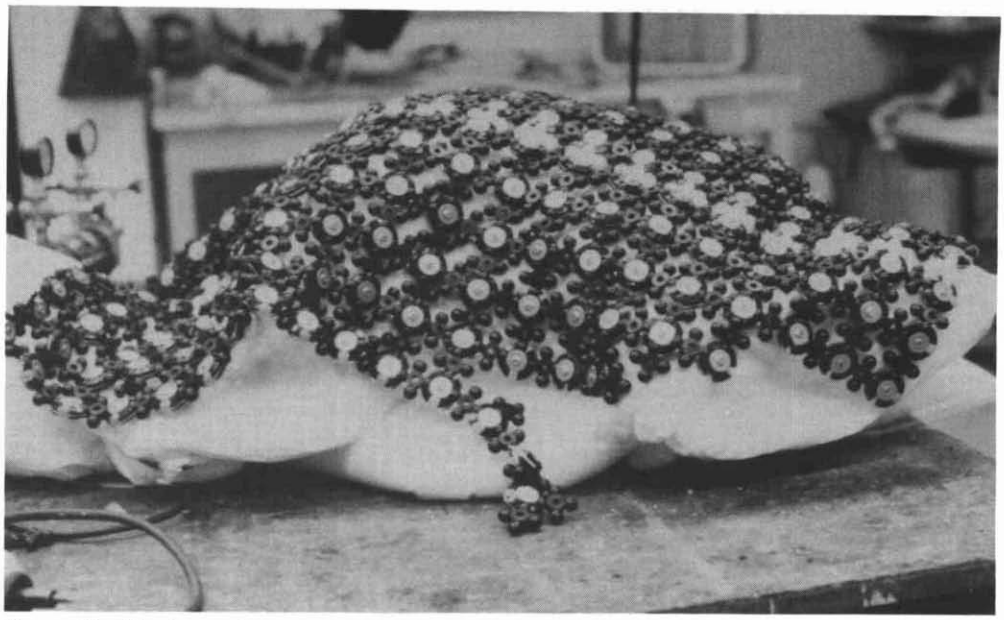

Figure 10. Matrix seating system.

arm trough when needed, making a whole system out of material unnecessary, unless preferred for the client.

These are brief descriptions of some of the newer systems on the market today. Information is available from the manufacturers to learn the benefits and weaknesses of all these systems (see suppliers list). The idea is to best provide the client with a product which, individually, does what is required for the most economical price. Having a variety of systems at our disposal, as well as the ability to custom fabricate components when necessary, will allow us to provide the best service to our clients and establish our facilities as specialists in this expanding field.

In Chicago, we have done just this by establishing the Chicago Seating Institute. At the facility, we specialize in proper positioning of clients, while providing various styles of seating systems, wheelchairs, and environmental controls. In the future, we hope to expand our field of expertise to include communication devices as well. Over the last few years, the development of the specialized seating side of our business has increased our volume from 12–15 clients a year in 1981 to 150–200 clients a year today. In no other area of our business could we have expected to see a ten fold increase in the number of clients seen, even with the same commitment made as we've done for specialized seating. The field of specialized seating is up and coming, not only for the orthotist, but the prosthetist and other allied health professionals as well.

Unfortunately, traditional education for specialized seating is not available. However, there are some programs and seminars offered, with increasing frequency in the past few years. Watch the upcoming issues of the American Orthotic and Prosthetic Association *Almanac,* or contact The Association for the Advancement of Rehabilitation Technology (RESNA) at Suite 700, 1101 Connecticut Avenue, Washington, D.C. 20036; (302)857-1199. Historically, as with orthotics and prosthetics, the best and only real way to learn, is to learn by doing. See your clients, and learn from making systems for them. This hands-on method is the best teacher for seating, because you can watch the clients expression to know if they are comfortable. The "cookbook" approach with easy rules just doesn't work here, since people do not demonstrate this reflex or that reflex, this deformity or that deformity, but a hodgepodge of various reflexes, deformities and contractures. Add to this, differing age groups, backgrounds, living conditions, and mental abilities, and the cookbook method becomes impossible. Have a variety of solutions at your

disposal. Think of the client as an individual. This education will help you understand your clients discomforts and needs, and with the help of a therapist, decide on realistic attainable goals. With this in mind, there are many ways to achieve the desired results of functional (where possible) and comfortable (always possible) seating for clients.

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[9] National Home Health Care Expo, Atlanta, Georgia. Call (305)773-2222 for details.

SUPPLIERS

BEAD SEAT
Pin Dot Products, 2215 West Belmont, Chicago, Illinois 60618. (Developed by The University of Tennessee Rehabilitation Engineering Program.)

CP SEAT
Pin Dot Products, 2215 West Belmont, Chicago, Illinois 60618. (Second generation of the MPI seating system developed by The University of Tennessee Rehabilitation Engineering Program.)

CONTOUR-U SEATING SYSTEM
Pin Dot Products, 2215 West Belmont, Chicago, Illinois 60618.

CRE
Creative Rehabilitation Equipment, 513 NE Schuyler, Portland Oregon, 97212.

FOAM-IN-PLACE SEATING SYSTEM
Carapace, Inc., P.O. Box 45040, Tulsa, Oklahoma 74147.

FREEDOM DESIGNS
Freedom Designs, Inc. 18165 Napa #8, Northridge, California 91324.

GILLETTE SEATING SYSTEM
Gillette Childrens Hospital, Orthotic Department, Minneapolis, Minnesota.

GUNNELL
Gunnell Manufacturing, 221 North Water Street, Vassar, Michigan 48768.

JAY CUSHION
Jay Medical Ltd., 805 Walnut, Boulder, Colorado 80302.

MATRIX SEATING SYSTEM
Pin Dot Products, 2215, West Belmont, Chicago, Illinois 60618. (Developed by Clinical Engineering Designs, Kingston upon Thames, England.)

MILLER'S
Miller's Rentals and Sales, 284 East Market Street, Akron, Ohio 44308.

MOSS (Modular Orthotic Seating System)
Otto Bock Industries, 4130 Highway 55, Minneapolis, Minnesota 35422.

PIN DOT MODULAR SEATING SYSTEM
Pin Dot Products, 2215 West Belmont, Chicago, Illinois 60618.

ROHO CUSHION
Roho, Inc. P.O. Box 658, Belleville, Illinois 62222.

SCOTTIE SEATING SYSTEM
Scott Therapeutic Designs, 430 Robertson Lane, San Jose, California 95112.

TORONTO SPINAL SUPPORT SYSTEM
The Hospital for Sick Children, 555 University Avenue, Toronto, Ontario.

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Prostheses to Achieve Independent Ambulation for a Geriatric Quadruple Amputee

by Gustav Rubin, M.D., FACS
Fred Harris, B.S., C.O.

The elderly quadruple amputee presents a challenge to a prosthetic clinic team. Although this problem is occasionally noted in children with congenital amputations,[1,2] it is much less commonly encountered in adults. During the past fifteen years there has been only one other total quadruple amputee—a young adult who was treated at our center and did not wish to have his case published.

Here we have the opportunity to present a report on the prosthetic fitting of a 64 year old veteran who was referred to our Special Clinic Team in 1981, from the VA Medical Center in Cleveland, Ohio, with a history of quadruple amputations secondary to frost bite.

H.F. was found on January 8, 1981, on a cold winter day, lying outside his home. He was unresponsive and had a rectal temperature of 77°. After a period of conservative care, amputations on all four limbs were done on February 4, 1981, at the private hospital in Canton, Ohio, to which he had been initially taken. The surgery resulted in a right wrist disarticulation, a left distal forearm amputation just proximal to the carpus, and bilateral below-knee amputations. The residual limbs healed without complications and the patient was transferred, on March 11, 1981, to the V.A. Medical Center in Cleveland, Ohio, where he was started on a course of physical and corrective therapy, including daily strengthening exercises to all four extremities.

He was considered highly motivated and an "excellent candidate" for prostheses. He was referred to our center, which was then the V.A. Prosthetics Center, and was examined by the Special Prosthetic Clinic Team on May 21, 1981.

H.F. also had a background history of gastrointestinal surgery ten years earlier for a perforated peptic ulcer. The report of the physical examination at the hospital prior to referral for prosthetic prescription revealed a normal cardiovascular examination, a blood pressure of 110/70, but a liver enlarged three cm. below the costal margin. The popliteal pulses were good.

The evaluation by the clinic team confirmed that H.F. was well-motivated. He was an intelligent, cooperative, slender individual, whose amputations were all well-healed. The right below-knee residual limb measured 4 inches to the bone end and the left below-knee limb measured 4½ inches to the bone end. There were mild knee flexion contractures which were not considered fitting problems. On the right below-knee limb there was a palpable, slight, irregular, distal anterior tibial bone prominence, unattached to the overlying tissues. On the left side the below-knee limb was poorly padded by soft tissue. As the examiner attempted to mimic piston motion of the soft tissue sleeve by drawing the soft tissue proximally, the distal skin, overlying a slight bone irregularity, blanched. X-rays of the left below-knee residual limb confirmed the clinical impression of bone irregularity and x-rays of the upper extremities confirmed the right true wrist disarticulation and the left amputation just proximal to the carpus at the level of the distal radius and ulna.

The amputee had been through a great deal (Figure 1) prior to referral to the Clinic Team and it was the consensus, at this time, that referral for a lower extremity revision would have adverse impact on his motivation. It was

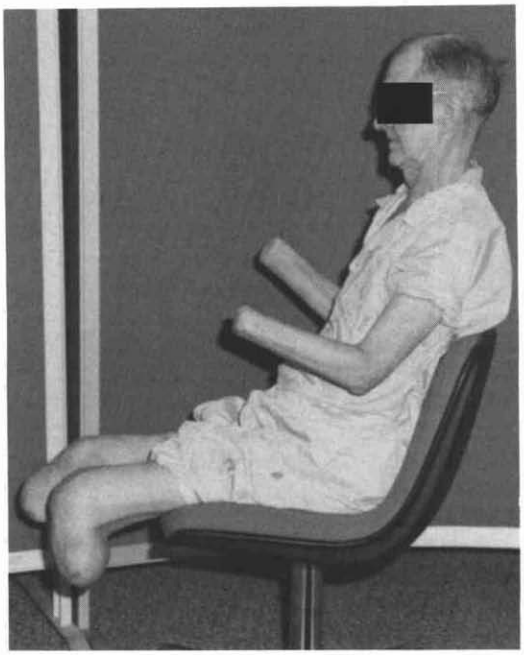

Figure 1. H.F., a 64 year old veteran and quadruple amputee.

the aim of the staff to make the patient as independent as possible by adapting the prostheses to his donning and doffing capabilities. PTS prostheses were prescribed to be fabricated with loops on the soft socket inserts (Figure 2) to aid donning. The prostheses for the upper extremities employed a Northwestern ring for the figure of eight harness, double wall sockets, friction wrists, and Dorrance Lyre hooks.

In addition, he was prescribed for platform crutches, which were modified with distal rings for the hooks and forearm loops (Figure 3). The forearm loops had to be pre-adjusted into a fixed position so that H.F. could slip the prostheses through the loops and avoid the need for repeatedly adjusting the Velcro® straps.

On June 11, 1981, fabrication of the below-knee prostheses was completed and the amputee demonstrated that he could stand and take several steps in parallel bars with assistance on each side. An exercise and training program with the prostheses was outlined at the hospital. The instructions included careful monitoring of the stumps during this time.

On June 18, 1981, the amputee was observed to be doing "extremely well," as indicated by the clinic team's notes. By this time he had also been fitted with his upper extremity prostheses and forearm crutches. He rapidly progressed to unassisted ambulation with crutches (Figure 4).

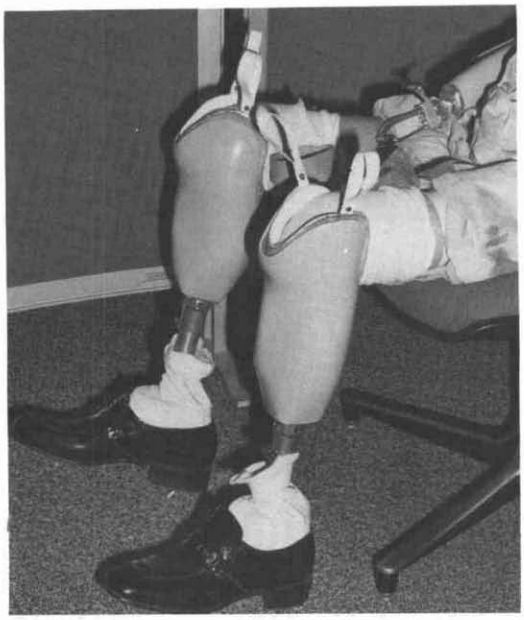

Figure 2. Below-knee prostheses were adapted with loops on the soft socket inserts to aid in donning.

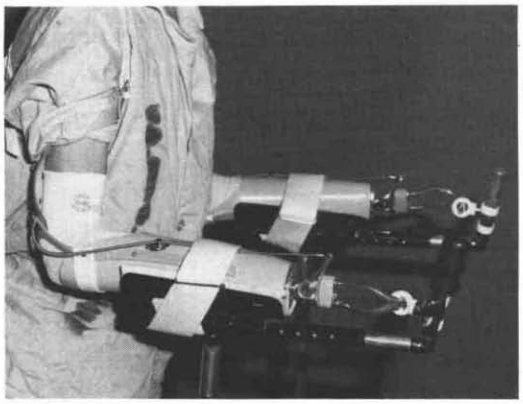

Figure 3. Platform crutches were also modified with distal rings for the hooks and forearm loops.

When seen by the clinic team on August 10, 1981, H.F. walked with the aid of a platform crutch. Because of irritation over the right ulnar styloid process, which was unresponsive to modification of the socket, a new socket was

prescribed incorporating a soft liner and he had no further problems with this.

On September 16, 1981, four months after his initial presentation to the team, H.F., who had been under continuous training by the Rehabilitation Service at the VAMC, NY, demonstrated that he was able to don and doff his own prostheses and even walk without crutches. He did, however, have more confidence when using one crutch. He was advised to continue using at least one crutch at all times. He reported the prostheses to be comfortable. Objectively, they appeared to fit satisfactorily and they were accepted. The amputee was returned to the VA Medical Center in Ohio. Subsequent attempted follow-up has been unsuccessful.

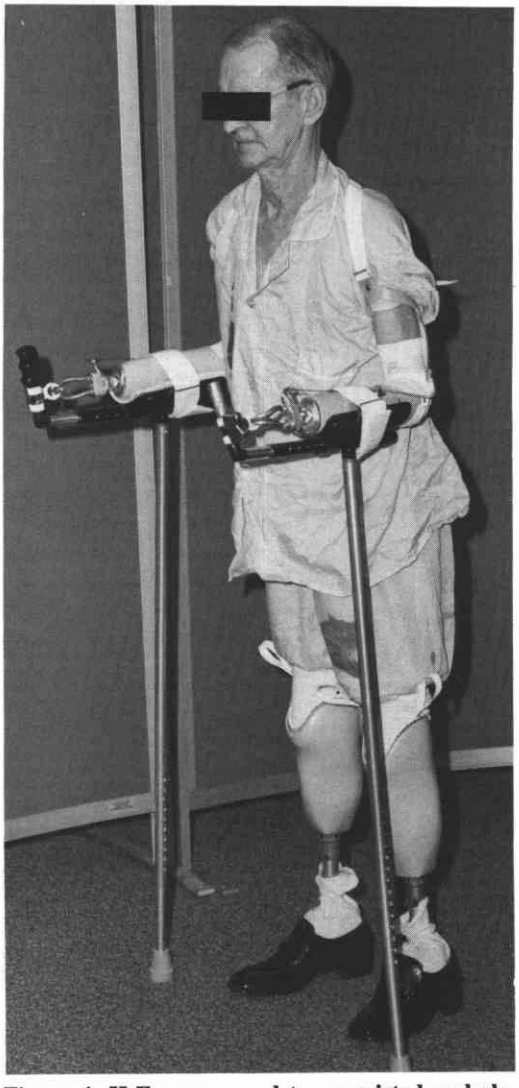

Figure 4. H.F. progressed to unassisted ambulation with crutches.

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AUTHORS

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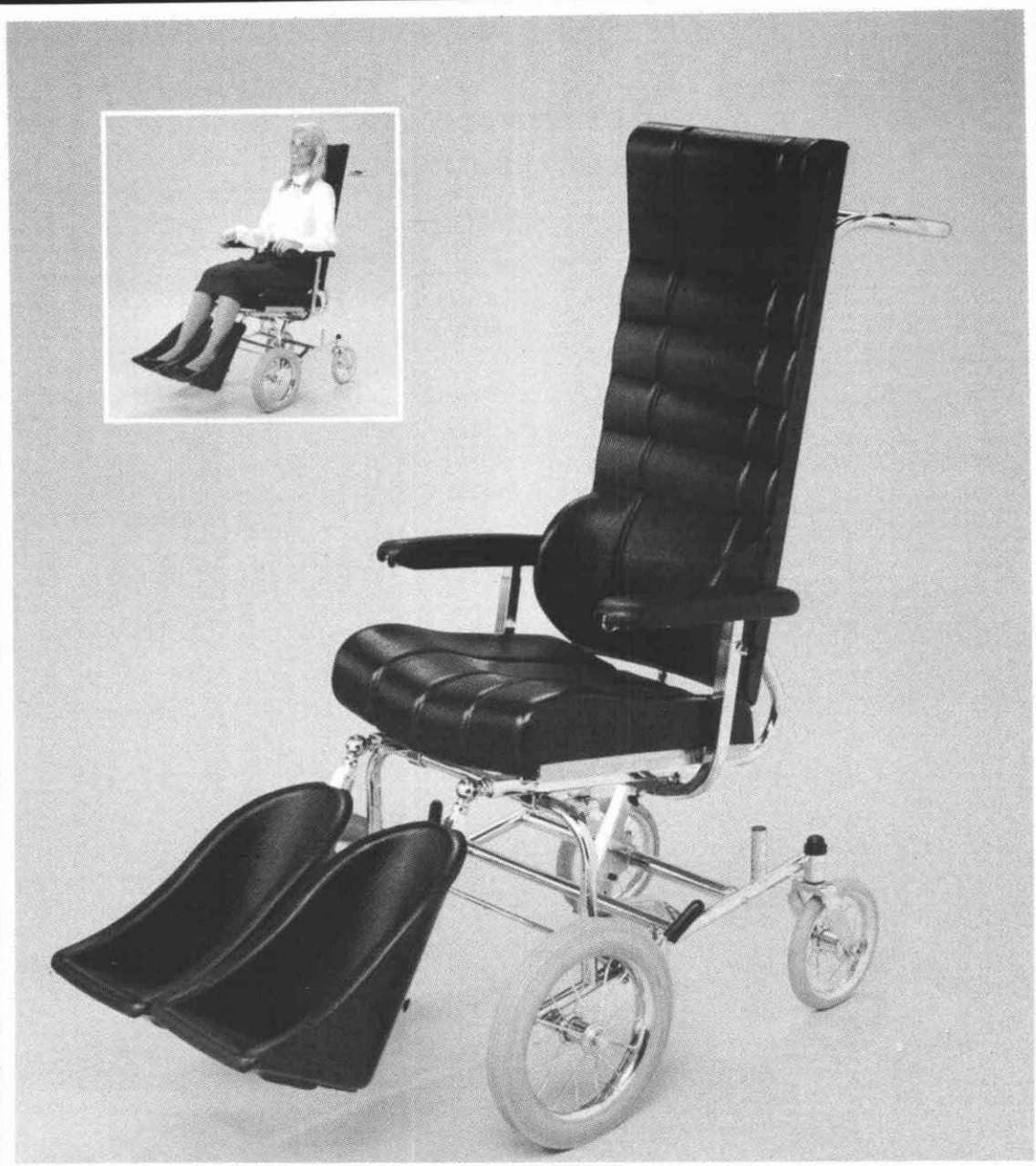
Fred Harris, B.S., C.O., is also with STAMP, NY.



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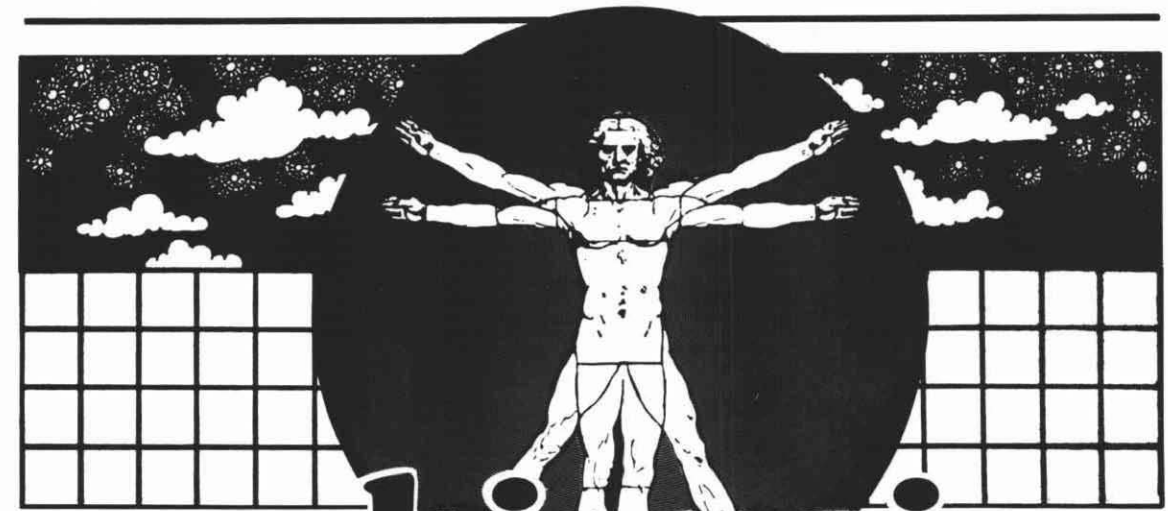

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Calendar

1986

October 22–31, UCLA Advanced Prosthetics Techniques, Los Angeles, California. Contact: Timothy B. Staats, MA, CP, UCLA POEP, Room 22–46, 1000 Veteran Avenue, Los Angeles, California 90024.

October 24–25, American Academy of Orthotists and Prosthetists Continuing Education Conference 5-86, "Spina Bifida," Cincinatti, Ohio. Contact: Academy National Headquarters, (703) 836-7118.

October 27–31, UCLA International Prosthetics Techniques Seminar, Los Angeles, California. Contact: Timothy B. Staats, MA, CP, UCLA POEP, Room 22–46, 1000 Veteran Avenue, Los Angeles, California 90024.

November 3–7, UCLA Course, Prosthetics and Orthotics for Physicians and Allied Health Professionals, Los Angeles, California. Contact: Timothy B. Staats, MA, CP, UCLA POEP, Room 22–46, 1000 Veteran Avenue, Los Angeles, California 90024.

November 4–9, AOPA Annual National Assembly, Marriott's Orlando World Center, Orlando, Florida, Contact: AOPA National Headquarters, (703) 836-7116

November 10–12, Hosmer Electric Systems Workshop and Seminar, Orlando, Florida. Contact: Catherine Wooten, Hosmer Dorrance Corporation, 561 Division Street, Campbell, California 95008; tel. 800-538-7748, (408) 379-5151.

1987

January 22–27, American Academy of Orthopaedic Surgeons, Annual Meeting, San Francisco, California.

February 15–22, Academy Annual Meeting and Scientific Symposium, Hyatt Regency Tampa, Tampa, Florida. Contact: Academy National Headquarters, (703) 836-7118.

March 9–12, 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.

March 16–25, 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.

March 30–April 2, 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.

April 13–22, 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 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 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 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.

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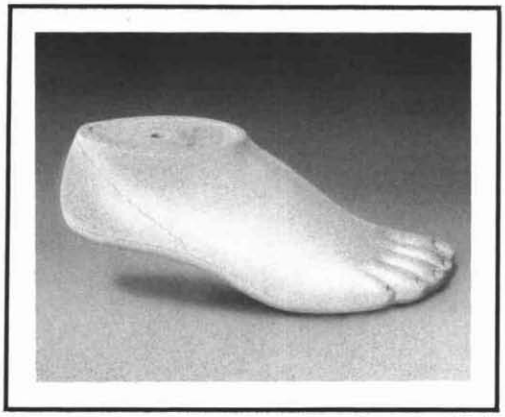

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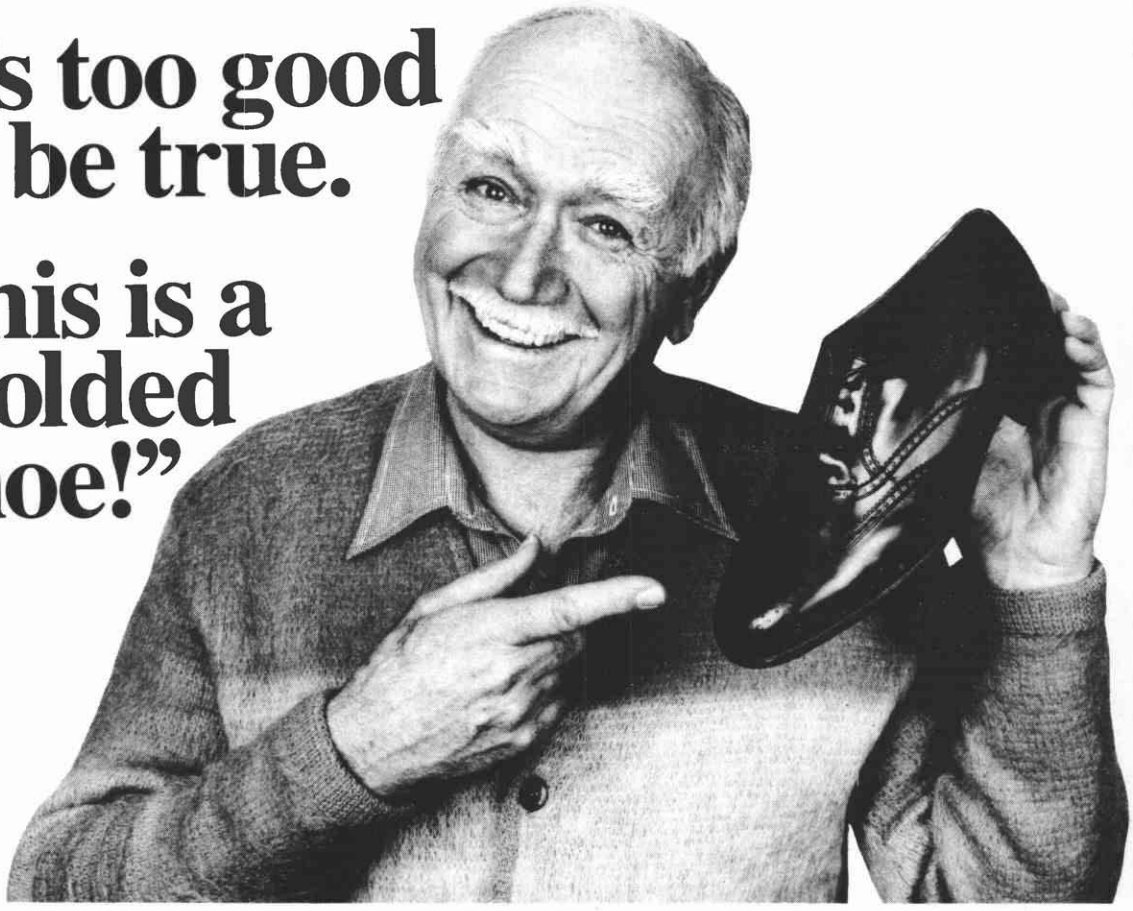

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