

Orthotic Management of the Paralytic Spine

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INTRODUCTION

Neuromuscular spinal deformity and its management have little in common with other idiopathic spinal deformities except for the collapsing effect of gravity on the erect spinal column and the role of skeletal growth. Individuals who are likely to develop neuromuscular deformities may lack protective sensation, refined automatic postural responses, muscle control, or all three. Orthoses designed for managing idiopathic scoliosis (IS) or Scheuermann disease are therefore very seldom appropriate for the treatment of neuromuscular spine deformity.

Spinal deformities associated with neuromuscular diseases vary widely and are dependent on severity and/or disease stage. A realistic orthotic goal is to reduce the rate of deformity progression during the growing years to either delay or avoid the need for fusion. Because orthotic treatment is seldom actually corrective, as it may be in IS, surgical rates are much higher for a neuromuscular than for the idiopathic diagnosis.

The vast majority of neuromuscular patients with spine deformity may use a wheelchair for mobility and other activities of daily life. They lack the control needed to maintain a level pelvis during the extensive daily periods of sitting. The paralytic circumstances, in combination with wheelchair function, constitute a profound difference between idiopathic and neuromuscular spinal deformity. However, realizing the important role of pelvic alignment exposes a powerful opportunity to provide useful orthopedic support. Therefore, much in this chapter is about sitting support. Seated patients present a set of challenges, considerations and opportunities that are, unfortunately, seldom part of the training or practice of orthotists. Because of the large number of patients within this group, it is important to know how to provide the best possible orthopedic spine support within a functional wheelchair.

In the authors' experience, there are five spine support devices that are very useful for people with neuromuscular spinal deformity: custom molded sitting support orthoses (SSO); non-molded sitting support systems; two-piece molded body jacket type thoraco-lumbo-sacral orthosis (TLSO); and fabric corset type TLSOs. The wheelchair lap tray is another very effective aid for reducing kyphotic collapse in addition to its more obvious functions. Each of these five devices has a place in the armamentarium of spinal support. The patient's diagnosis, severity and age dictate the appropriate choice.

Of these devices, the SSO, in its many variations, is the most practical and effective but very underutilized except at a few specialized centers. The plastic shell TLSO is frequently advocated in the literature in spite of its limited pelvic control and how the rigid confinement negatively impacts the patient's already marginalized balance and upper body function. It is best suited for short-term use, for resisting curve progression during a growth spurt or following spinal fusion. This TLSO is usually not prescribed for wear at night or other periods of extended recumbence. The exceptions would be in post-fusion cases when the

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surgeon is unsure of the internal fixation or bone quality.

The fabric corset TLSO is very interesting because, for many patients, the pulmonary function benefits are more important than the spinal support it provides. Both spinal support and the pulmonary benefit of this orthosis occur only when the patient is sitting or standing. This orthosis is also used much less often than is justified by its value.

The wheelchair lap tray may seem like an unlikely item to include in this orthotic text. It was discovered early at Gillette Children's Specialty Healthcare (GCSH) that simultaneously addressing both spine support and upper body function results in significant additional benefit for both.¹⁻³

When a person cannot walk, he/she carries out most daytime functions of life from a seated position. The adequacy and safety of their sitting environment (i.e., wheelchair with a seating and adaptive equipment system) profoundly affect self care, comfort, work, and general health. A high percentage of people who permanently function from a seated position have either profound, extensive loss of protective skin sensation, or profound loss of trunk control motors, or both. Muscle tone abnormalities, either high or low, in the absence of well defined sitting support often lead to mal-positioning, which in turn, contributes to orthopedic deformities. These can develop very rapidly in growing children. It makes sense to utilize the daytime hours as fruitfully as possible to not only provide the needed functional stability, but also the orthopedic support and control necessary to resist the progression of spine, pelvic, and lower extremity deformities.

The transition from a flexible mal-alignment to structural orthopedic deformity may occur in adults as well as children, but it proceeds at a much slower rate. In the adult non-ambulatory population, there is a much higher incidence of pressure ulcers because of the different diagnostic mix and the impaired skin health. When a custom orthotic seating system can effectively intervene regarding pressure sores and/or orthopedic deformities, it is very cost-effective. The expense of long term care for people with those chronic issues is immense.

MAXIMIZING UPPER BODY FUNCTION

The importance of facilitating and improving function is perhaps paramount when we provide devices for long-term use. With that in mind, it is helpful to be aware of an over-arching physical control principle critical to optimizing patient function. Patients with a neurological impairment generally exhibit a top-down control hierarchy. For instance, if a patient with cerebral palsy (CP) has very minimal voluntary control of body segments, it will most likely be some control of the neck and the head. Head and neck control is then improved if or when control is improved when the upper spine is in good, stable alignment. Lesser impaired patients will have some control of shoulders and upper limbs. Improved function of any of those segments requires either active or passive stability of the next lower body segment from which it arises. Likewise, functional alignment and control of the upper spine depends on a stable lower spine, which in turn, depends on its base, the pelvis, for firm alignment.

The orthotic system should, therefore, improve and control the alignment of the pelvis and the spinal segments going upward far enough to meet the patient's level of voluntary control. Terminating support too low will fail to facilitate all of the patient's potential function. Carrying support too high will

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deprive the patient of the opportunity to fully develop voluntary movement capability.

SPINE MECHANICS

The un-impaired human head-neck-trunk-pelvic complex receives its stability partly from the spinal column acting as a loosely connected stack of vertebrae that can support compression loads. A multitude of short deep paraspinal muscles and ligaments contribute stability and alignment between neighboring vertebrae. Longer, larger and more superficial muscles provide power for controlled movements of the vertebral column. Among that second group are the abdominal muscles. An able bodied individual also has the very important proprioceptive and voluntary control necessary to maintain stability of the sacrum and pelvis that serve as the base of the spinal column.

The foundation is vitally important to the stability of any structure, especially if the structure is a vertical column. A fundamental engineering concept is that the stability, i.e. resistance

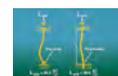


Fig 1

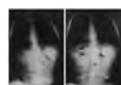


Fig 2

to buckling, of a longitudinally loaded column depends greatly on the “end conditions”.

When the base end of a column is constrained to prevent tilting or rolling, the column can bear twice the load before beginning to bend/buckle.⁴ The column buckling analysis is not an exact approximation of the spinal column (Fig1). However, clinical experience and radiographs have shown that the engineering column analysis has significant validity (Fig 2).

The importance of controlling alignment at the base of the vertebral column applies in all planes. The left diagram (Fig.3) depicts the kyphotic collapse posture commonly encountered. Posterior tilt of the pelvis can be resisted by how the thigh, pelvic and lumbar support surfaces work together. Anterior support to the upper thorax is often needed for children with cerebral palsy.



Fig 3

It is important to be very aware of the spine-stabilizing role of the abdominal wall muscles. Normal abdominal wall muscles actively constrain the abdominal viscera. Circumferential constriction causes the abdominal contents to act hydraulically upward on the diaphragm and other thoracic contents while also

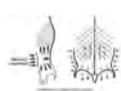


Fig 4

acting downward upon the pelvic floor.⁵ When the abdominal muscles are contracted, the result is a reduction of the abdominal circumference. The abdominal wall and viscera become a hydraulic column, a sort of anterior strut, relieving the spinal column of a large amount of axial and forward bending load (Fig 4). The orthopedic implication, of course, is that when the neurological

condition creates flaccid abdominal muscles, we should definitely consider orthotic approaches to abdominal circumferential control. Patients with cerebral palsy seldom need corset or wide belt devices because of their existing muscle tone. However, these orthotic additions are commonly beneficial for other neuromuscular conditions without muscle tone.

PATIENT EVALUATION

Specialists in wheelchair seating know that for people who are not ambulatory, there is a profound relationship between seating design and all aspects of life. Health, function and other needs are interwoven in highly individualized ways. We must recognize this to approach optimum outcomes. Custom seating design is a process involving the discovery of problems, hopes and opportunities that may not become

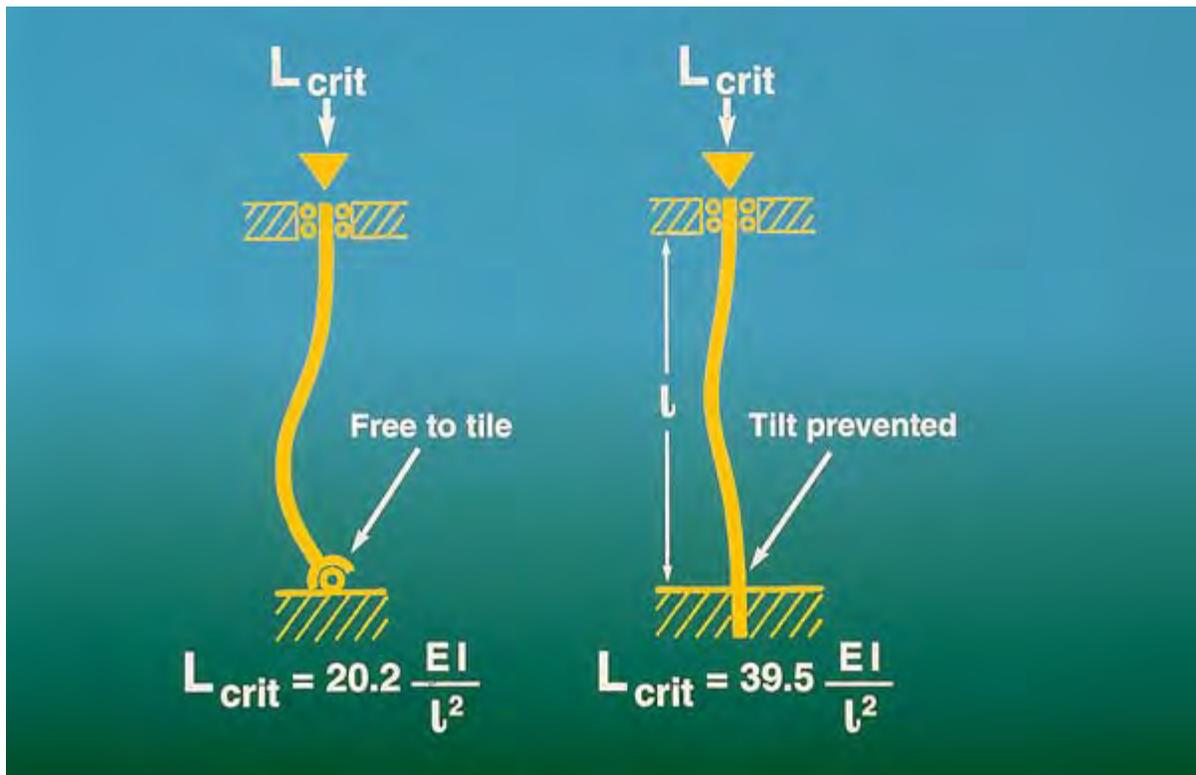


Fig 1 - Classical and experimental mechanics have quantified the stabilizing benefit of controlling alignment of the base end of a flexible, longitudinally loaded column. Constraining the base doubles the load required to buckle the column.

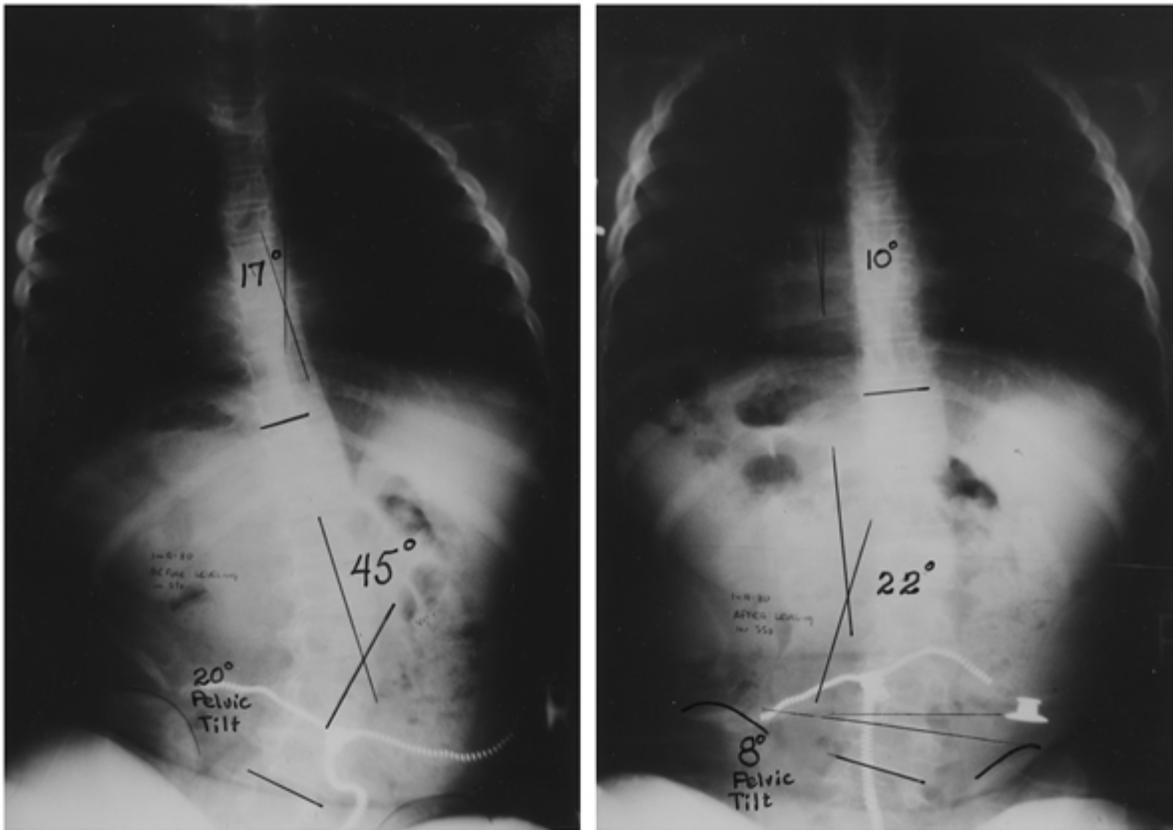


Fig 2 - This set of radiographs demonstrates the power of controlling pelvic alignment. The radiograph on the left is of a boy with MD placed in his wheelchair and SSO without attention to pelvic alignment control. The radiograph on the right was taken an hour later after performing the pelvic leveling procedure. *Note: See republican permission notes in acknowledgements.*

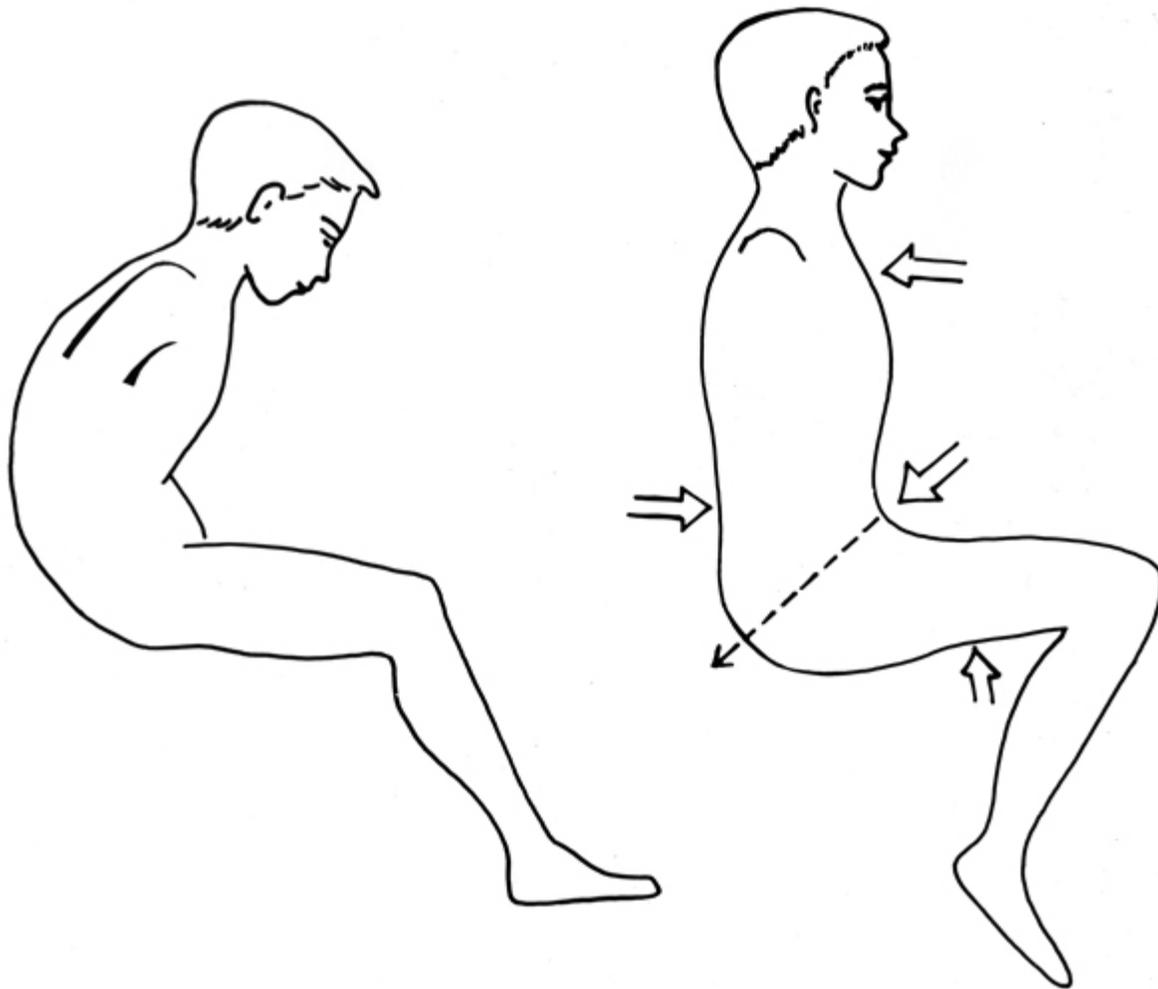
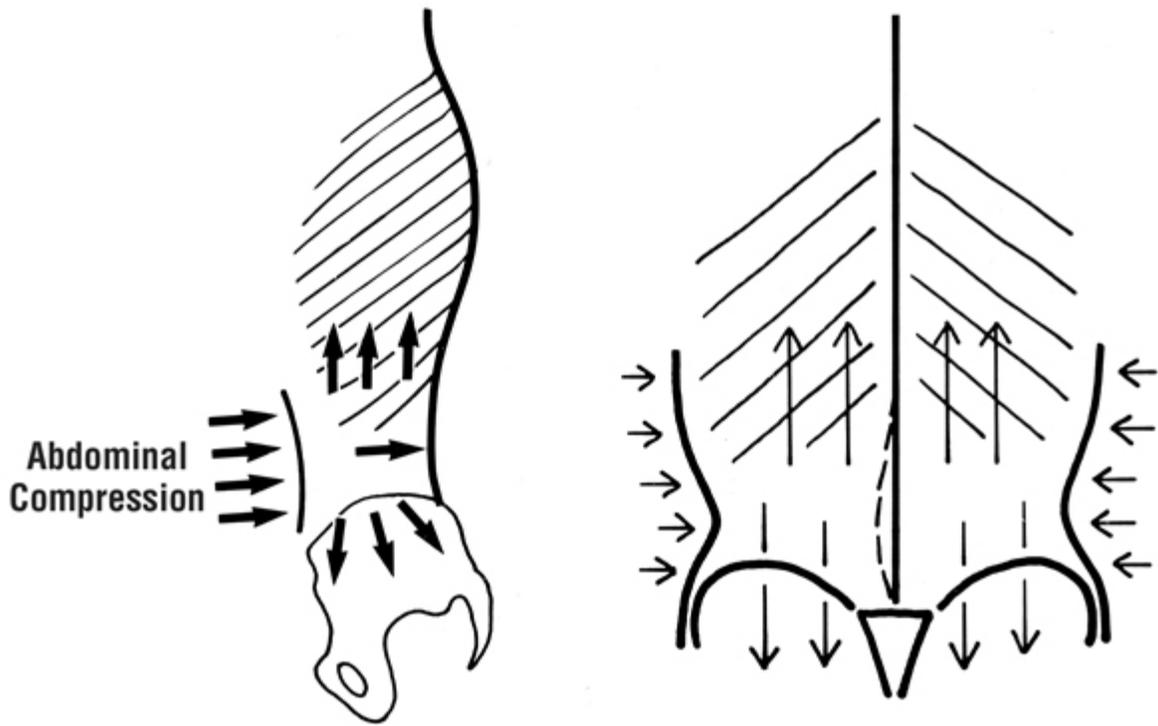


Fig 3 - The diagram on the right indicates the family of support forces required to correct the kyphotic collapse represented on the left. (From "Seating for children and young adults with cerebral palsy". *Clinical Prosthetics and Orthotics*. 1987; 11 (3): 176-198, published here with permission from American Academy of Prosthetics and Orthotics (AAOP).



Abdominal compression causes
an increase in intra-abdominal pressure

Fig 4 - Active abdominal wall musculature plays a large role in enabling the spinal column to extend under load. When those muscles are flaccid, passive corset constraint allows upper body weight to be borne downward to the pelvis via the abdominal hydraulic column. (From "Seating for children and young adults with cerebral palsy". *Clinical Prosthetics and Orthotics*. 1987; 11 (3): 176-198, published here with permission from American Academy of Prosthetics and Orthotics (AAOP)).

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clear until the fitting and trial stage of orthotic system delivery.

In addition to the physician and orthotist, it is important to solicit and invite input from family members, other caregivers and advocates which may include the classroom teacher. The excellence of the outcome depends heavily on starting out and proceeding with comprehensive information and input of ideas and concerns. Some adult clients, of course, have an independent life style and can advocate for themselves very clearly.

During the evaluation process, which may last from 60-90 minutes, discussion should cover quite a range of topics and issues. First obtain a very clear idea of what the client and principle caregivers expect the seating system to accomplish. Following that, discuss, observe, and examine to get a picture of the client's status with regard to functional ability, orthopedic status, skin sensation, muscle tone abnormalities, wheelchair operation, etc. Evaluators should also learn what seating and wheeled mobility equipment the client presently has, what they have had in the past, and what has and has not worked well. Also discuss issues such as transportation, residential situation, work, recreation, and other lifestyle factors. All of these will impact the design of the seating system in some way.

The creative aspect of designing the patient's seating and mobility system begins during the evaluation. Ideas, no matter how radical, that the participants might have should be expressed. These ideas, particularly those of the client, are very important to ensuring the success and value of the outcome. By the end of the evaluation, all members of the team should have a solid concept of how specific issues will be addressed in the final design. It is important for one person on the evaluation team to summarize what is planned in writing and distribute the document to the rest. That document serves as a certificate of medical necessity (CMN) when there are third party payers involved and should contain a complete rationale for the most important design features of what will be provided. It is a vital document useful in many ways. It is signed by the evaluating care professionals and by the prescribing physician. Appendix A contains an example of a form for recording information obtained during the evaluation, CMN examples typical for CP and Spinal Cord Injury (SCI) diagnoses, and a form to record information needed by fabricating personnel.

CEREBRAL PALSY

Approximately 25% of all children with cerebral palsy (CP) will develop scoliosis.⁶ The incidence rises to about 60% for those children classified as spastic quadriplegic. Most children with CP of Gross Motor Function Classification System (GMFCS) levels IV and V⁷ are not ambulatory by the age of about 10 and usually do not develop good independent sitting ability. Patients in this subgroup are the ones most likely to develop spinal deformities of consequence. If they are not provided quality sitting support, most of them slump into a single, long kyphotic or kypho-scoliotic curve with a postero-laterally tilted pelvis (Fig 5).



Fig 5

Within the GMFCS IV and V classification levels there are large variations in the extent and complexity of the sitting support system needed. Some of these patients will need only pelvic and low thoracic components. Others will need passive alignment up to and including the head.

If pelvic mal- alignment and spinal column collapse are left to progress unchecked, cardio-pulmo-



Fig 5 - This photo illustrates a typical unsupported sagittal posture of a child with GMFCS level IV CP. The hands only prevent lateral tipping.

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nary function may become compromised. During adult years pressure ulcers may also develop and care may become very difficult and expensive.

Goals

Many of the goals of the orthotic and adaptive equipment system for people with severe CP also apply to other neuromuscular diagnoses. When the seating and adaptive equipment system is complete it should enhance virtually all functions, for both the patient and his/her family. For instance, when a patient cannot eat independently, it will make it easier for a caregiver to feed him/her. It will improve the patient's field of vision, increase his/her comfort and maximize his/her level of independence. A functional seating system improves the patient's education and social development, creating a more enjoyable existence for the entire caregiving family.

A wheelchair mounted lap tray is almost always an essential component of the adaptive equipment for GMFCS IV and V patients. In addition to being a functional surface for reading, writing, communication devices, etc., the lap tray almost always serves an orthopedic purpose as well. When closely fitted and installed at the right height, the patient's elbows and forearms will support a significant portion of the weight of the patient's upper body. The lap tray (Fig 6), padded if necessary, will then relieve the spine of a considerable flexion bending moment. This will markedly reduce thoracic hyperkyphosis so the patient is able to more actively maintain a more erect, functional, attentive and cosmetic posture.



[Fig 6](#)

The orthopedic issues in CP are caused by the neurologic problems so it is important to reduce muscle tone and minimize spastic reflexes. By incorporating body positions, which reduce reflex patterns into the seating system, upper body function will be improved and the progression of deformities may be reduced. This is a very prominent consideration in the design of the Gillette SSO and will receive more discussion later.

Wheelchair seating safety issues are very important to consider. (Automobile seat safety requirements vary and will not be addressed here.) First, a safety belt must wrap around the child and seat and be anchored to the wheelchair with an easily released buckle. Most wheelchairs can be equipped with posterior anti-tip components. On many wheelchairs, rear wheel position may be adjusted to create a longer wheelbase. The potential for forward overturn of the patient, equipment and wheelchair as a whole is addressed by positioning the patient adequately back and down in the wheelchair. Often that requires special recessing adaptations for both seat and wheelchair. See appendices B and C.

Gillette Sitting Support Orthosis (SSO)

The Gillette SSO was developed to address the progressing deformities and functional needs of the many youngsters with severe CP arriving at that institution. Those children presented a wide variety of neurologic and orthopedic conditions. With regard to spinal deformity, it was recognized that these non-ambulatory patients needed pelvic alignment control that could not be provided by a TLSO. The GCSH position on the inadequacy of a TLSO for this patient group was corroborated by Olafson, Saraste and Al-Dabagh⁸ who reported dismal results from Boston Brace treatment of a group of 66 non-ambulatory neuro-



Fig 6 - This lap tray with padded elbow-forearm areas allows the arms to reduce the flexion load on the thoracic spine.

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muscular patients.

The Gillette SSO proved to be very user-friendly and an effective spinal orthosis for this population (Fig 7). Its effectiveness was due, in part, to providing enough comfortable hip flexion



Fig 7

to greatly reduce initiation and strength of the hip-knee extension spasms that often exhibit overflow to the upper spine and limbs. As an orthopedic device, it affords a way

to manage pelvic alignment, thoracic support and even cervical and cranial control as needed (Fig 8).

Fig 8

The SSO shell is a thin strong structure that fits closely where support is needed. Because the thermoplastic shell is thin, thoracic support can extend high into the axillae without blocking upper limb adduction needed for comfort and function (Fig 9). The open front of the SSO serves an important function. It allows easy palpation of the iliac crests to observe the degree of lateral pelvic tilt and guide adjustment during donning. The shell is rigid enough for mounting the essen-



Fig 9

tial pelvic belt as well as a wide variety of headrest, head control and thoracic support panels.

Fabrication of a Gillette SSO begins with obtaining an impression of the patient's dorsal and lateral surfaces in the seated alignment necessary to achieve the neurologic and orthopedic goals.

This is best accomplished with a special casting frame (Fig 10). The process of obtaining the impression, fabricating and fitting are described in appendix B.

Fig 10

The completed Gillette SSO, like any orthopedic device, must be properly donned or, in this case, "gotten into". The non-ambulatory patient with cerebral palsy is likely to experience some hip extension reflex and increased tone when caregivers transfer him/her into the SSO, preventing the pelvis from sinking down and back into the pelvic area of the SSO. After loosely fastening the pelvic belt and locking the wheels, the caregiver should proceed to the back of the wheelchair. With wheels locked, he can then tip the wheelchair, SSO and patient about 45 degrees posteriorly, leaning the upper back of the wheelchair against his midsection. In this position, which recruits the help of gravity, it is easy to tuck the patient's pelvis down and back well into its proper location in the SSO and to straighten his pelvis at the same time. If the patient has scoliosis, his pelvis will tend to tilt laterally in the direction of the scoliosis convexity. If the scoliosis curve is convex right, the right side of the pelvis will be lower than the left. The caregiver must pull upward on clothing at the right hip area to level the pelvis as much as possible. Simultaneous downward pressure on the opposite side will assist this correction. This procedure is referred to as "pelvic leveling" and is easily accomplished with the wheelchair leaned back against the caregiver as described above. Immediately after the pelvis is leveled, the SSO lap belt should be fastened snugly. The wheelchair may then be returned to its upright orientation and the safety belt secured.

Before caregivers take the wheelchair seating system home, and at every other opportunity, proper positioning and pelvic leveling should be reviewed. In addition, caregiver education includes a discussion of how long a child might be expected to remain seated; the importance of checking for reddened areas; and the need for regular, frequent clinical assessment and modifications by the seating specialist.

Because of its durability, the SSO can serve an adult for more than a decade with minor periodic refurbishing. When provided for a growing child, the shell should include removable pelvic growth pads bilaterally at the greater trochanters. These may be thinned and finally removed as the child grows. Strategic



Fig 7 - This is an example of one SSO configuration. This one has shoulder straps and a removable pommel. This SSO has been adapted, along with the wheelchair for recessing into the chair. Also visible is the pelvic control strap that is a necessary component of virtually all SSOs for patients with CP.



Fig 8 - These are two examples of SSO head supports.



Fig 9 - The thin polypropylene material of the SSO shell is rigid enough to support the thorax as necessary with very minimal bulk. Bilateral thoracic support extends into the axilla areas without blocking shoulder adduction. (From "Seating for children and young adults with cerebral palsy". *Clinical Prosthetics and Orthotics*. 1987; 11 (3): 176-198, published here with permission from American Academy of Prosthetics and Orthotics (AAOP)).

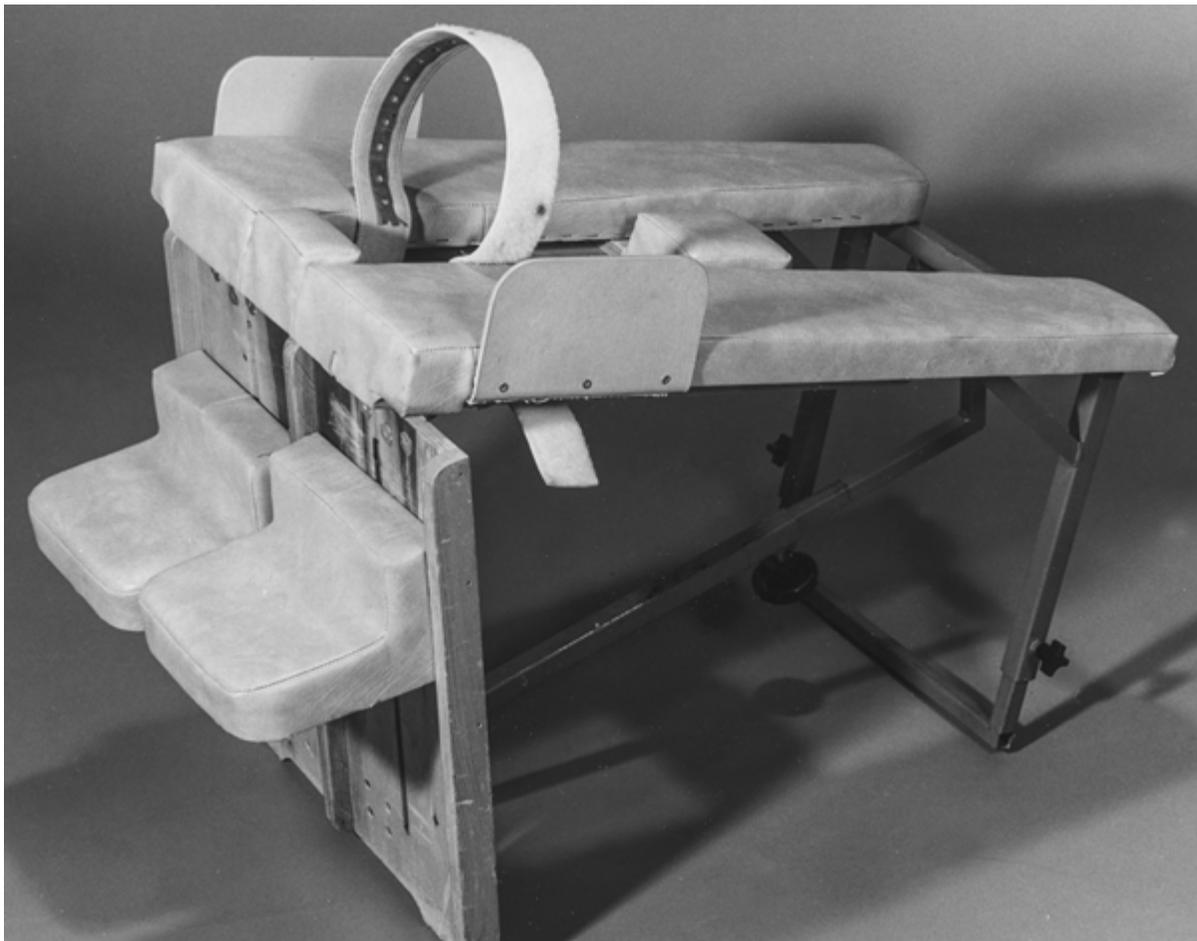


Fig 10 - This is a photo of a Gillette SSO casting fixture. (From "Seating for children and young adults with cerebral palsy". *Clinical Prosthetics and Orthotics*. 1987; 11 (3): 176-198, published here with permission from American Academy of Prosthetics and Orthotics (AAOP)).

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heating and reforming of the postero-lateral quarters may accommodate thoracic width increase. Vertical sub-axillary extensions can be welded onto the shell if and when thoracic support needs to extend higher. If the technician is adept at making such modifications, the SSO will serve a school age child for between two and three years.

In some parts of the world, technical labor is very expensive and premanufactured seating components are commonly utilized. Those systems are available in many sizes and are very adjustable to meet a spectrum of head, neck, spine and pelvic support needs. The biomechanical principles presented earlier should be a valuable guide regarding how to select and fit premanufactured systems.



When circumstances prevent provision of either the Gillette SSO or premanufactured sitting support systems a more rectilinear sitting support (RSS) may be the next choice (Fig 11). In this case, the seat fabrication starts with a wood or plastic frame sized to the individual. This design may be either a free standing unit or it may be attached as components to a stroller or wheelchair. The frame is appropriately padded and upholstered. Thoracic and head supports are mounted as needed. The rectilinear frame designs also may be a very adequate choice and preferred in cases where scoliosis concerns are minimal and closely conforming orthopedic support is not required. The fabric corset-type TLSO can be used in combination with an SSO but that is rarely beneficial for CP patients who usually exhibit good abdominal muscle tone.

[Fig 11](#)

Some ambulatory children with CP do develop scoliosis. When this is the case, a plastic shell TLSO may be useful to control progression during the growth spurt.

DUCHENNE MUSCULAR DYSTROPHY

Approximately 90% of boys with Duchenne Muscular dystrophy (DMD) will develop a significant spine deformity.⁹ The scoliosis begins to develop after they become non-ambulatory. If they manage to prolong ambulation into the teen years, the spine begins to acquire a full-length lordosis. These youngsters carry that fairly stable posture into their years of wheelchair use (Fig 12). Boys who stop ambulating earlier are likely to develop a severe kypho-scoliotic deformity including, of course, a mal-aligned pelvis. Spine fusion, where available, is the preferable option to avoid the consequences of allowing deformity to progress.



[Fig 12](#)

Goals

As with CP, managing a spinal deformity for a patient with muscular dystrophy (MD) is not an isolated goal. It must be tempered and tailored for a best fit with other very important interwoven goals. To the extent that they can be addressed individually, the five main goals will be discussed in the following order: optimize comfort; optimize upper limb-hand function; manage spinal deformity; preserve or improve pulmonary function; and be as safe and stable as practical.

Providing adequate comfort in the sacro-pelvic area is a challenge for all MD patients. Pain associated with prolonged pressure and friction-induced shear at supportive bony areas are major issues. If the patient's seat cushion can reduce pressure, shear, moisture and heat, he will be more comfortable. He will need repositioning and unweighting less frequently, thereby reducing caregiver burden. Complete informa-



Fig 11 - These are three examples of rectilinear frame type sitting support.

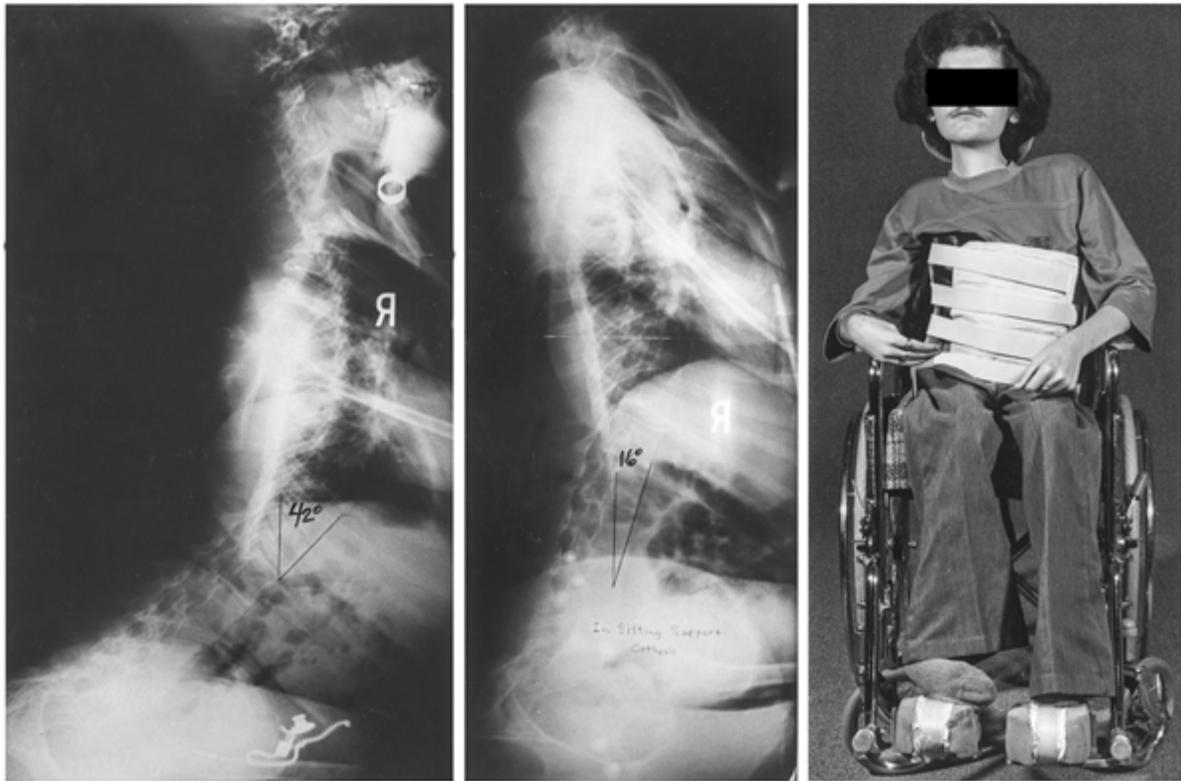


Fig 12 - On the left is the lateral radiograph of a young man with MD as he presented to clinic. The center image is his radiograph in his SSO. On the right, he sits in his SSO with the abdominal panel, which comfortably reduces his hyper-lordosis and corrects his posture. See republication permission notes in acknowledgements. (From "Modern Orthotics for Spinal Deformities". Clinical Orthopaedics & Related Res. 1977; 74-86, Wolters Kluwer, with permission).

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tion for alleviating pressure, shear, moisture and heat is found in the section on spinal cord injury (SCI).

With properly designed sitting support and adaptive equipment, these young men can retain hand function until their disease is very advanced. That optimum function depends on several things:

- An easily adjustable anterior support strap, anchored to the SSO that allows them various degrees of forward body incline. A bandolier style strap works well and is cosmetically more acceptable than a horizontal chest strap;
- A lap tray closely and securely mounted on the wheelchair at a height determined by self-feeding, writing and joystick trials; and
- A forearm bolster located on the lap tray under the forearm near the elbow of the patient's dominant side to act as a vertical and horizontal pivot point. Without such a little bolster the patient will often "crawl" his non-dominant hand across to act as the lift and swing fulcrum for his dominant forearm. Just like the lap tray, trial and error will determine optimum bolster thickness and placement. The non-dominant hand can then be employed as a helper to stabilize items on the tray.

With the right amount of forward incline and lap tray set-up, a patient may be able to bring his hand to his mouth by simultaneously lowering his head, dominant shoulder and upper arm. His forearm will pivot at the bolster to raise his hand toward his mouth. Writing, drawing, gaming, keyboard operation and using a powered chair joystick are possible even with limited movement of the upper extremity and shoulder.



[Fig 13](#)

If a spinal fusion is not performed, boys with MD do best if they receive a fabric TLSO for use with their custom SSO soon after fulltime wheelchair use begins. In this case, a comfortable, symmetrical, corset TLSO can be fabricated from measurements (Fig 13). The combination of pelvic alignment and hydraulic spinal support will provide patient comfort and function until a fusion is performed. The TLSO should be of a tailored heavy-duty corset material reinforced with flexible stays. The abdominal support needs to be flexible to allow for some forward bending, and air permeability for moisture and temperature moderation. Two corset TLSOs should be provided because each must drip-dry for about 24 hours after laundering.



[Fig 14](#)

The seating expert who must provide wheelchair spine support for an MD patient with an unfused spine and already severely collapsing kypho-scoliotic spine has a challenge of heroic magnitude. Scoliotic collapse progresses rapidly if the pelvis is free to tilt laterally. The spine deformity quickly loses flexibility and becomes very severe including a pelvis that cannot be completely leveled. Comfort issues become very difficult to manage. In such cases, a cast and model of the patient's torso may have to be obtained for corset fabrication. Fabric panels may then be fit to the model and sewn into a more shape-conforming corset (Fig 14).



[Fig 15](#)

A well-fitted corset TLSO and SSO combination can provide powerful spine stability and improved comfort if caregivers consistently use the pelvic leveling procedure described earlier (Fig 15). More information about the Gillette SSO appears in the cerebral palsy section and in appendix B.

It is especially gratifying when one fits an orthosis to achieve a certain benefit and discovers a sur-



Fig 13 - A fabric corset TLSO is a comfortable, substitute for some of the function of abdominal muscles. Circumference and shape may be adjusted easily to accommodate weight changes and optimize pulmonary function. Some patients do not need it to extend as far up the thorax as the examples shown. (From "Seating Orthosis Design for Prevention of Decubitus Ulcers". JPO. 1995; 7 (2): 51-60, published by Lippincott Williams & Wilkins, with permission from AAOP).



Fig 14 - When spine deformity has become quite severe, the corset TLSO must be fabricated to a plaster model. Corset panels are pinned or clamped together directly on the cast to obtain custom panel shapes needed for proper fit.

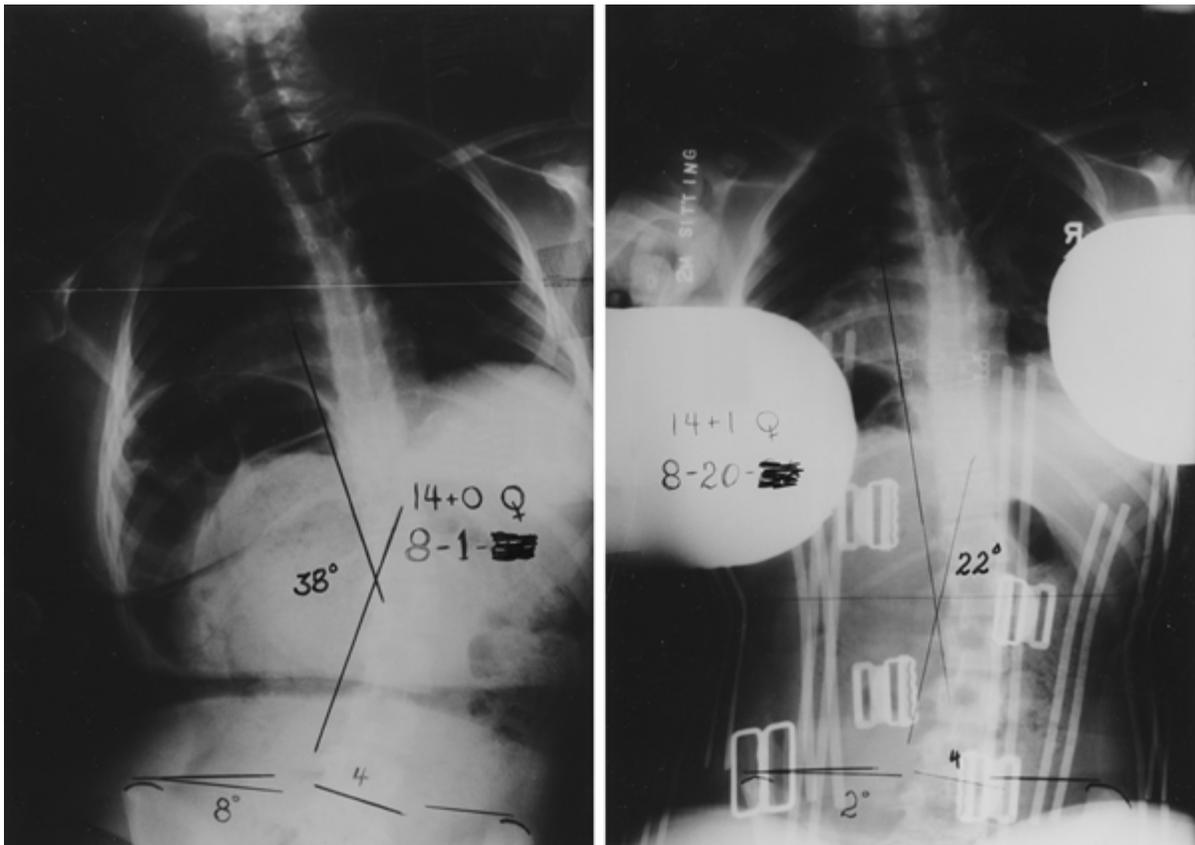


Fig 15 - The radiograph on the left is of a 14-year-old girl with a diagnosis of CP. She presented with flaccid abdominals, rare for her diagnosis, and a flexible collapsing scoliosis. The radiograph on the right was taken one month later after providing her an SSO and corset TLSO. (From "Seating for children and young adults with cerebral palsy". *Clinical Prosthetics and Orthotics*. 1987; 11 (3): 176-198, published here with permission from American Academy of Prosthetics and Orthotics (AAOP)).

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prise additional benefit. In the biomechanics analysis near the beginning of this chapter, we discussed how a fabric abdominal corset type TLSO reduces axial and bending loads on the spine. Such a corset has been provided for many patients with flaccid abdominal wall muscles. Quite by chance, we discovered that, in addition to spine support, some of those patients also gained significant pulmonary function benefits including stronger voices, stronger coughs, and less anxiety.

The secondary pulmonary benefit was discovered when we straightened the sitting posture of a boy with MD who was very slumped forward in his wheelchair. When we brought his shoulders up and back, extending his thoraco-lumbar spine, he could not adequately breathe. In that straightened position the opening between his rib margin and pelvis was enlarged, allowing abdomen to protrude and pull down his diaphragm. His compromised inspiration caused him great anxiety. The simple answer to improve both posture and lung function was a fabric corset with circumferential adjustability. Circumferential constraint can then be titrated to best satisfy the patient.

Safety concerns relating to dynamic overturn instability have been mentioned earlier in this chapter. Boys with muscular dystrophy are very conscious of susceptibility to forward overturn. Most will refuse to use a system that places the center of gravity (CG) of their body too far forward and/or elevated relative to the wheelchair.

SPINAL MUSCLE ATROPHY

Spinal muscular atrophy (SMA) comprises a spectrum of severity levels. Type I SMA is evident in infancy. It is the most severe type. Types II and III begin to develop later in childhood. The three types represent more of a spectrum of severity rather than distinctly separate types. Scoliosis develops in virtually all of the most severe, type I cases, most of the type II and approximately half of the type III.¹⁰ The spine progressively loses stabilizing musculature and tends to collapse under the influence of gravity.¹¹ Pulmonary function will then decline.

The SSO and fabric TLSO are the most appropriate orthoses for SMA. The biomechanical considerations for improving spinal support and pulmonary function are very similar to DMD.

SPINAL CORD INJURY

If the spinal cord injury (SCI) occurs before the age of 10 years, a secondary spine deformity will develop.¹² Spine fusion before the deformity becomes severe is usually recommended where available. However, the vast majority of spinal cord injuries happen later, near the close of, or after, physical maturity. This reduces the probability that scoliosis will develop. If it does, a laterally tilted pelvis is almost always part of that deformity.

Most of the muscles which contribute to thoraco-lumbar stability and control are segmentally innervated. In addition, a spinal cord lesion may be incomplete and/or asymmetric. Consequently, it is wisest to evaluate the sensory level, volitional control, pulmonary function and story of the patient rather than rely on a specific lesion level report. As with all neuromuscular diagnoses, each patient presents you with a specific combination of sensory level, abilities, concerns, aspirations and critical information about his activities of daily living and work-life.

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Following acute stabilizing surgery, a rigid TLSO, with cranio-cervical components when necessary, may be used to help maintain stability of the fracture site until the fusion is solid. As a result of the improved stability of new implants not orthosis may be necessary. As the rehabilitation process continues and the fusion matures, maintenance of a functional posture becomes very important. People with low paraplegic level lesions have considerable voluntary trunk control. They can sit very erectly and can easily straighten up after bending forward.

Most people with paraplegia secondary to SCI live independently soon after they are discharged from rehabilitation. They typically use a lightweight, highly maneuverable manual wheelchair with a low lumbo-sacral back support, a cushion and no lateral supports. Freedom of movement within the wheelchair is key to realizing their functional potential.

Progressively higher lesion levels leave the SCI patient with less control of spinal musculature. People with low quadriplegia level lesions may be able to be independent in most activities of daily living. Most can, at least for some years, use a manual wheelchair. Their upper body function depends on trunk stability achieved through a “slumped” posture, that is, a very kyphotic thoraco-lumbar spine supported on a posteriorly tilted sacro-pelvic base. This posture provides a fairly solid base for upper spine, shoulder and arm function. That partially collapsed posture also provides close upper extremity access to the manual drive wheels. It seems counterintuitive, but for certain lesion levels, some degree of postural slump also facilitates pulmonary function. The downside of the slumped sitting posture is that it makes it more difficult for the thighs to share some of the upper body weight. The consequence is greater peak skin surface pressure and friction loading on the sacrum and ischial tuberosities.

People with high quadriplegic level lesions need a full-length posterior support and bilateral thoracic supports in combination with several degrees of recline. It is highly recommended that the seat bottom and back recline as a unit.

Decubitus Ulcer Prevention

People who use wheelchairs for daily mobility and function, specifically those with impaired sensation such as the case with SCI, are at constant risk of developing a serious sub-pelvic or sacral ulceration. Decubitus ulcers, also called pressure ulcers, destroy careers, marriages and quality of life. Septicemia secondary to these wounds is a common cause of early death among people with spinal cord injury. It is extremely important that we focus on prevention because of the severe consequences and because each occurrence or reoccurrence of a stage III or IV ulcer multiplies the difficulty of preventing the next one. Even in parts of the world where the best “off-the-shelf” adjustable cushions are available, some decubitus ulcer issues are so severe that a custom fabricated cushion is prescribed. In all cases it is important that providers understand seat cushion design features that will help prevent decubitus ulcers from developing.

The first step in prevention is a full understanding of the direct causes operating at the ulcer site. There are four physical conditions at the skin surface of potential ulcer sites that contribute to tissue trauma and which seating design can affect; those four are: pressure, friction, temperature, and moisture.

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Pressure

Of the four, pressure is the most obvious. When contact pressure is too great, blood cannot flow in to bring oxygen and nutrients to the cells nor remove toxic metabolic byproducts. If that high contact pressure persists too long, cells die. This is the ischemia model.

We know from long experience that excessive pressures occur where skeletal elements lie close to the skin surface in weight bearing areas. There are three ways to reduce those peak pressures; with cushioning materials; by structural shaping of the supporting surface; and with fluid flotation.

Cushion materials increase weight bearing contact area and thereby reduce peak pressure. However, those vulnerable locations continue to be where the tissue is subjected to the highest pressure. Orthotists and prosthetists know from long experience that shaping of the contact surface is an effective way to transfer forces away from bony, intolerant, areas. Areas of deeper soft tissue are more load tolerant. So, just like in a shoe insole or trans-tibial socket, a very good approach is to use a combination of shaping with only as much cushioning as is necessary to off-load at-risk areas. However, it is difficult to precisely locate, size and shape support surfaces to lower all peak contact loading.

Fluid flotation is the third method listed above but has some negative characteristics and limitations. To truly float the user, the fluid must generate a weight-resisting pressure when in use. If the fluid is air, leakage can reduce user protection to zero, sometimes without the user's awareness. Also, a totally fluid support surface reduces the opportunity to transfer significant load from the pelvis forward onto the thighs.

Finally, with regard to pressure, we must understand the role of the wheelchair footrest. If the wheelchair footrest is too elevated, it will totally negate any efforts to transfer weight-bearing pressures from the pelvis to the thighs. The posterior thighs have no bony prominences and can safely bear higher pressures than the ischial tuberosities. Weight can be shifted from the pelvis to the thighs by shaping a gentle thigh fulcrum into the structural material of the seat cushion in the area of the proximal thighs. See the exaggerated depiction on the left of figure 16. The footrest may then be adjusted lower so that the femurs act like levers. The lower leg weight operates on the lever to partially lift and reduce pressure under the pelvis. The mechanical equivalent appears on the right of figure 16. It is interesting to observe that when we occasionally sit on a table we soon place our hands under our proximal thighs. The weight of our distal thighs and dangling lower legs and feet reduces pressure at the ischial tuberosities. Pelvic unweighting is enhanced even more if we lean our upper body forward a bit. This feature in a wheelchair cushion works the same way to enhance the benefit when a person with SCI leans forward.



Fig 16

The ischemia model for pressure ulcer generation has been useful and has dominated cushion design almost exclusively. The other three factors have received too little attention from cushion designers. This is unfortunate. Additional strides in prevention of these wounds are possible when we give more attention to technologies that will reduce skin friction, temperature and moisture in at-risk tissue areas.

Friction

Friction, the second in our list of contributors to tissue trauma, is not as easy to visualize as pres-

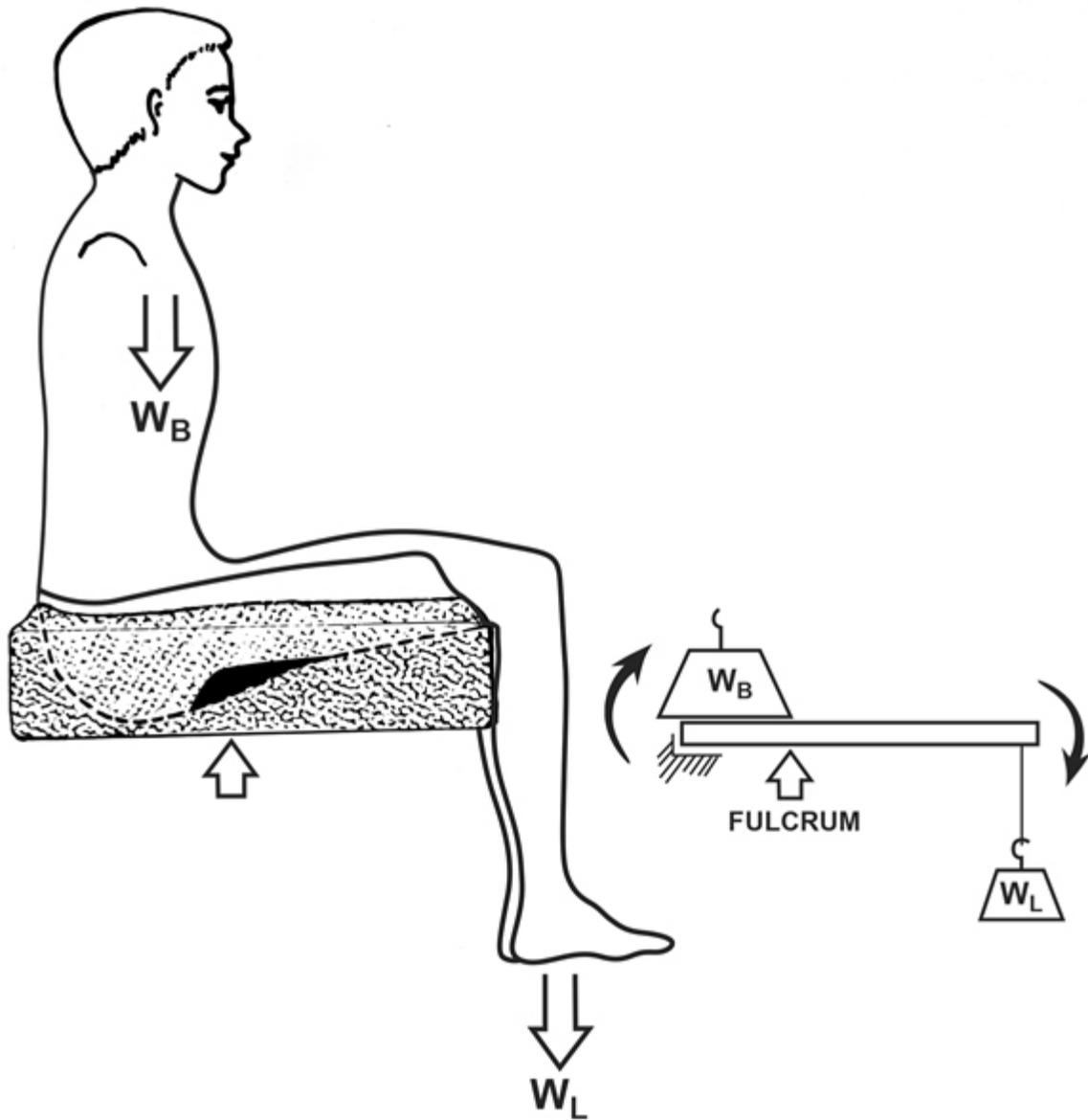


Fig 16 - This sketch and diagram illustrate how the 1st class leverage of the distal thigh and lower leg weight uses a thigh rocker seat contour to reduce pelvic pressure. The thigh rocker also increases the sub-pelvic unweighting that occurs when the user leans forward. The thigh rocker is exaggerated in the patient sketch. . (From "Seating Orthosis Design for Prevention of Decubitus Ulcers". JPO. 1995; 7 (2): 51-60, published by Lippincott Williams & Wilkins, with permission from AAOP).

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sure. Friction force is important because it profoundly elevates shear distortions within the soft tissues. Shear is a type of tissue deformation in which neighboring levels/layers of the tissue are dragged or pulled parallel to each other. Friction on the skin surface is a kind of skin traction. The direct result of this kind of loading is shear stress and strain in nearby soft tissue. Some shear conditions are present within the soft tissue under all loading conditions. This is especially the case in close proximity to bony prominences. Benet's research¹³⁻¹⁵ found that surface friction induced shear stress of 100g/cm² when superimposed on simple pressure, causes capillary blood flow occlusion to occur at much lower pressures than in the absence friction. More specifically, he and his colleagues found that an ulcer could be generated in approximately half the time under those circumstances. Since it is well established that friction-induced shear distortions contribute to the formation of ulcers, it is important to know how we can minimize shear.

There is a common misconception that shear damage can only occur as the skin slides across a contact material. In fact, friction and accompanying shear stress at significant magnitudes do not go away once the person has settled into his wheelchair. As a person settles to a resting position, friction has a role in exactly where movement stops within the seat cushion. Friction is, in fact, traction on the skin directly subjecting skin and soft tissues to a shear distortion. Static friction forces may actually be greater than when sliding is occurring. Friction, and the soft tissue shear it causes, can persist and do its damage all during the many static hours of wheelchair use or bed use.

There are two ways to minimize shear. The first is by reducing the friction needed to keep the client in his/her chair. The tendency to slide is reduced by creating a recess in the cushion that cradles the pelvis and then slopes upward toward the distal thighs. Providing lumbar and other back support to bring the wheelchair user to a more upright, less kyphotic, posture will also help. When the patient is quadriplegic, one must be careful, of course, not to bring the client too close to the forward tipping point unless he has anterior thoracic support.

The second way of minimizing shear is to provide a very slippery interface under the specific at-risk areas. Friction is bad only in ulcer prone locations. In other areas, where the layer of soft tissue is thicker, friction contributes to sitting stability and causes no problems. Unfortunately lubricating agents quickly seep and spread beyond the area of application. In a short time, they cause skin hydration and mix with exfoliants. The result is that the mix on the skin surface becomes somewhat sticky which is a very unhelpful development. Selecting the right materials for the interface at a specific location can almost totally eliminate friction forces without lubrication.

The amount of friction-induced shear trauma is governed by the natural "grippiness" or "slipperiness" of materials between the skin and the support surface. The friction characteristic of a given pair of materials is measureable and known as the coefficient of friction (COF). When materials do not slide easily across one another, that pair of materials has a much higher COF than a pair of materials that glide easily across one another. Most material combinations exhibit a measured COF between 0.2 and 0.9 but a few COF values can be outside that range.

Friction can be managed strategically by locating an area of very low COF material under the bony areas and using a mid-range COF, commonly available fabric or foam material in all the other weight bearing areas (Fig 17). During the hours of sitting, bony area movements remain within



Fig 17

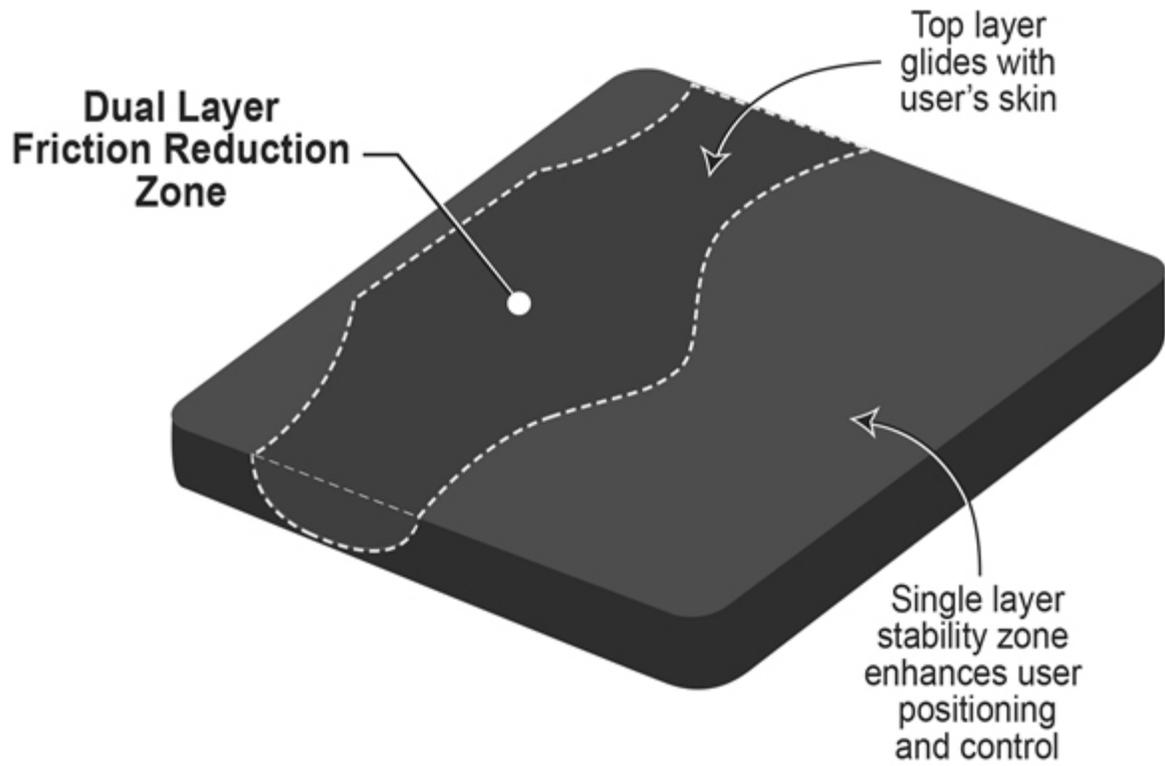


Fig 17 - The seat cover in this illustration has low friction material sewn into the sub-pelvic area only.

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the low COF zone. This arrangement allows the skin covering the bony prominence to glide those small amounts along with the bone as the user goes about his/her activities of daily living. The COF and friction in the more extensive, less vulnerable areas, is higher and provides the needed stability.

Temperature

Elevated temperature and moisture are the third and fourth localized surface conditions contributing to pressure ulcer generation. These two are partially interrelated because evaporation reduces both. Temperature is a factor because a one degree centigrade rise in temperature will increase cell metabolic rate by approximately 10%.¹⁶ In other words, if we can keep vulnerable tissue a bit cooler, the onset of cell death will be delayed.

Moisture

Moisture is last on this list but not the least important. In addition to possible unhealthy skin reactions to the contents of urine and sweat, we know that moisture weakens the outermost layers of the epidermis. Moisture also tends to increase at the skin-fabric interface and any other fabric interfaces located between skin and support surfaces.

Materials with good wicking characteristics and/or which allow air to circulate close to the skin may facilitate both reducing heat and moisture. If the cushion and/or the cushion cover are air-permeable, moisture may be evaporated reducing both moisture and temperature at the skin surface. Unfortunately, many cushions are made of materials that insulate, preventing moisture and metabolic heat from escaping. When a client has a demonstrated pressure ulcer risk, the professional caregivers should consider every one of these four contributing factors.

It should also be mentioned that some covers significantly cancel much of the benefit of a well-designed cushion. An ideal cover should be of a material that easily stretches in all directions. Such a material allows the body to immerse into the deeper contours of the cushion with minimal resistance or folding.

Pulmonary Function

Some people with quadriplegic lesions present with shallow breathing and weak cough. Because of very shallow pulmonary function, some cannot speak louder than a whisper. Similar complications were mentioned earlier for MD patients. Pulmonary function issues are encountered so frequently among cervical level SCI patients that it should be routine to perform a quick test. The test consists of applying a moderate amount of passive static abdominal compression to see if it will make a significant difference. When the test is positive the patient should receive a fitted fabric jacket. The improved breathing, coughing and in some cases, voice volume will be remarkable.

A literature search indicated that these clinical findings are consistent with what speech and pulmonary function researchers have reported.^{17,18} It is unfortunate that corsets are not more frequently prescribed. The gentleman in (Fig 18) was a classical demonstration of these pulmonary function issues. He had an SCI for many years when referred for improved sitting support. All during the initial interview his left fist was poked a few inches into his midsection. When asked about the reason



[Fig 18](#)



Fig 18 - This gentleman kept a fist poked into his flaccid abdomen to improve his pulmonary function.

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for this, he seemed hardly aware of that habit but said it just made him feel better. He had found his own solution to being able to breathe a little better. Unfortunately, it cost him the ability to use that arm and hand for other things. A fabric abdominal jacket TLSO or even an abdominal binder would be a better solution.

People living with quadriplegic level SCI have a limited ability to perform the periodic unweighting maneuvers that help prevent pressure sores. They need wheelchair cushions of the very best quality and many also need powered tilt-in-space wheelchairs. The tilt-in-space feature preserves the occupant's entire posture and seated joint angles as it tilts backward to reduce the weight on sub-pelvic surfaces. It is the safest way to mechanically unweight while remaining in a wheelchair.

Wheelchairs, which recline the backrest while leaving the sitting surface horizontal, create large shear-producing friction loads on all weight-bearing skin from head to thighs. Those friction forces are further elevated as, and after, the backrest is moved back toward vertical. There are very few patients for whom this type of wheelchair is appropriate.

Slings are sometimes the best way to transfer a patient between bed and wheelchair. Transfer slings should be carefully removed when the transfer is complete. If the sling is not removed after each transfer, it should be designed to insure that none of the sling material remains between the pelvis and the cushion after the transfer. Sturdy sling fabric remaining under the pelvis could negate the effectiveness of the wheelchair cushion.

MYELOMENINGOCELE

The myelomeningocele malformation causes severe, localized spinal instability because of the severe posterior defect with a resultant angular kyphosis. In addition there is often additional neuromuscular scoliosis or scoliosis related to congenital vertebral anomalies. The incidence of hyperkyphosis and/or scoliosis varies from 52% to 90%.¹⁹ Spinal orthoses have a limited role in the management of spinal deformity in this diagnosis. The area of the myelomeningocele lesion lacks the posterior bony structure and spanning muscle system required to resist kyphotic collapse. Spine support devices must avoid any forceful contact in the area of the kyphotic gibbus where such force would otherwise be mechanically effective. In fact, special modification is often necessary to ensure that area is protected from any forceful contact.



[Fig 19](#)

Plastic shell TLSOs are sometimes used to resist deformity progression while the child is very young (Fig19). This can allow some vertebral growth and development before fusion. The TLSO should be a two-piece shell to facilitate gentle, precise placement during donning. The gibbus, when present, must be protected by a non-contacting bulge in the orthosis. The same or a similar TLSO may be used to protect alignment after surgery while the fusion solidifies. The major spine support benefit of the TLSO in this case probably comes from the hydraulic effect of the snug abdominal containment of the plastic shell. The TLSO is not used at night except when needed to protect the area of the lesion or when used for post-fusion stability.

Many older children and adults with myelomeningocele will find a wheelchair to be the most practical means for everyday mobility and daily living. They will have some degree of impairment of lower body

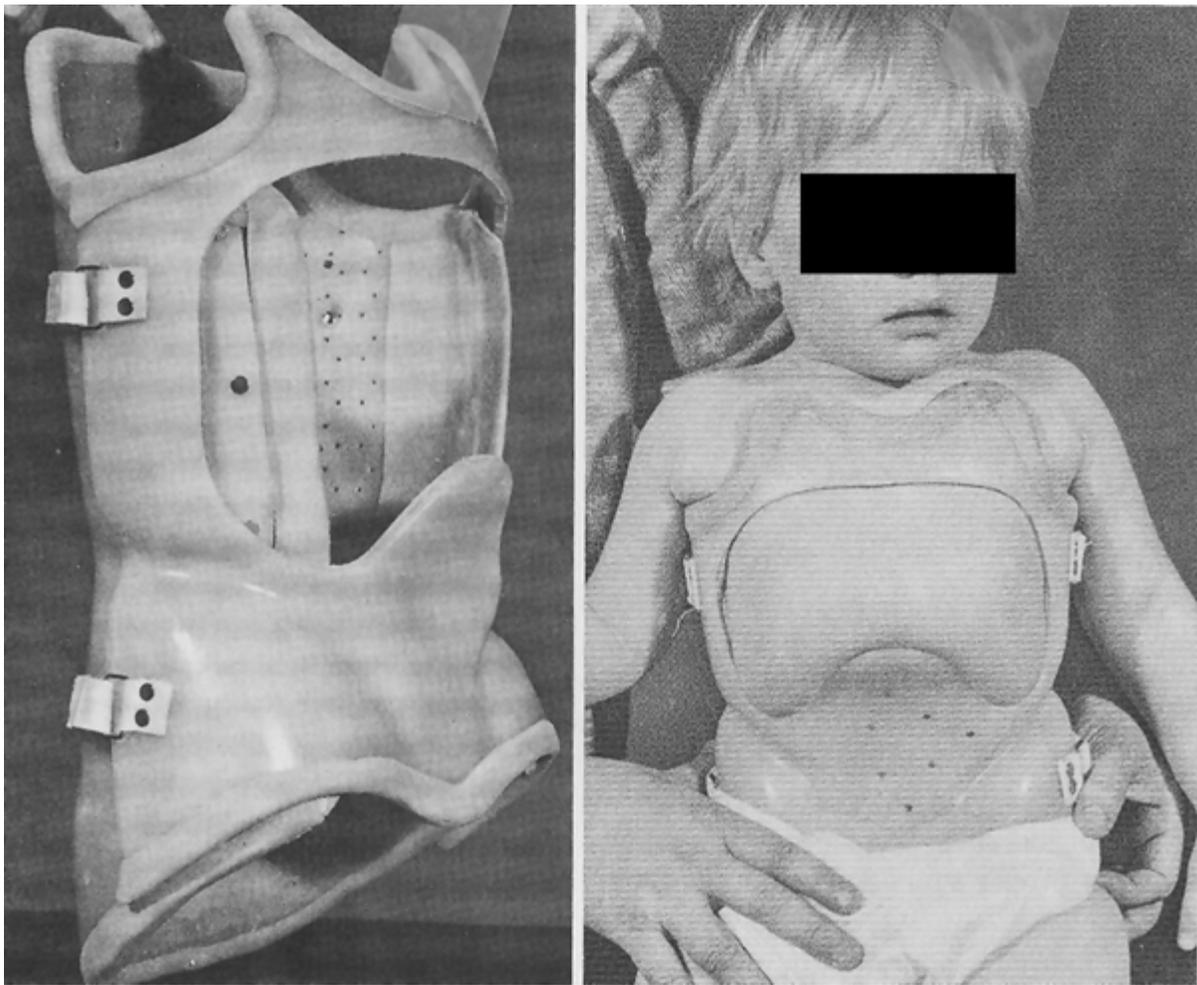


Fig 19 - The two-piece plastic TLSO should include flexible tongues along each side of the overlapped edges of the posterior shell to prevent pinching. . (From "Modern Orthotics for Spinal Deformities". Clinical Orthopaedics & Related Res. 1977; 74-86, Wolters Kluwer, with permission).

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sensation and will present skin protection needs similar to those presented by people with SCI.

POLIOMYELITIS

In an unpublished written communication to John Fisk in 2014, Hugh Watts observed that, “Scoliosis as a result of polio paralysis, broadly speaking, is seen in two groups of children.” He observed that the more severe group, who have extensive trunk muscle paralysis and develop scoliosis very early, cannot pull away from pads applying support pressure. The children of the less severe group have more voluntary trunk control and the spinal deformities, which develop more gradually, tend to remain flexible longer. Functional sitting may be possible in spite of a collapsing spinal deformity. The authors of this chapter have encountered a small number of adult polio survivors who are dependent on a wheelchair for movement outside of home but have some ambulation ability within the home in spite of a severe, flexible spine deformity. Those individuals relied on corsets of leather or fabric to provide them with a comfortable modicum of trunk support.

The first author’s limited experience and Watts’ report would suggest that plastic shell spinal orthoses are not appropriate for poliomyelitis patients. Some sitters and marginal ambulators with a flexible, collapsing spinal deformity will benefit from a well-fitted, circumference-adjustable fabric LSO or TLSO. Adjustability of the circumference of the corset is important because pulmonary function is optimized at some mid-range abdominal constraint level. The swing-to crutch ambulators will find that the corset moderately reduces the energy required for ambulation. The abdominal constraint decreases the amount of spinal collapse each time as ambulation transitions from shoulder weight bearing to pedal weight bearing.

Finally, some of the polio patients will present with a neuromuscular condition and functional needs similar to what is encountered by people with MD, spinal cord injury or some combination. See those sections of this chapter for custom orthotic seating information.

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The authors acknowledge that Tamarack® Habilitation Technologies is the manufacturer of two low-friction interface products. Address inquiries to: J. Martin (Marty) Carlson (martyc@tamarackhti.com) Tamarack Habilitation Technologies, Inc. 1670 94th Lane NE, Blaine, MN 55449-4323.

[APPENDIX A](#)

[APPENDIX B](#)

[APPENDIX C](#)

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Appendix A

APPENDIX A

Evaluation Information Form
CMN Example for Patient with CP
CMN Example for Patient with SCI
Measurement Form

Appendix A

SEATING/POSITIONING EVALUATION

Client: _____ Date: _____

Address: _____

_____ Tel: _____

Birth Date: ___/___/___; Soc. Sec. No.: _____ Ins. Priv.; MC; MA

Referrer: _____ Physician: _____

P.T.: _____ O.T.: _____

Orthotist: _____ Location of Eval: _____

Present at Eval: (in addition to client and orthotist)

Name Address Telephone

INFORMATION & OBSERVATIONS

(Continue on backside when necessary)

A. 1° Diag: _____ 2° Diag: _____

B. What does client want us to do: _____

C. Specifics of Condition:

1. Skin: _____

2. Spine: _____

3. Other Orthopedic Consid: _____

4. Muscle Tone: _____

5. Upper Extremity: _____

6. Pulmonary Function: _____

7. Pain: _____

8. Other: _____

D. Present Function:

1. Sitting Posture/Alignment: _____

2. W/C Transfers: _____

3. W/C use: ___:___ to ___:___ / ___:___ to ___:___ / ___:___ to ___:___

4. Desired w/c use: _____

E. Present Equipment

Past Equipment (good/bad)

1. W/C _____

2. Cushion _____

3. Other _____

4. What is working well _____

F. Transportation issues: uses med. Cab; priv. van; priv. sedan;

G. (Re) Habilitation Opportunities: _____

H. Mock-up Evaluations Tests and Trials done: _____

Appendix A

I. Recommendations:

1. Custom Seating Type:

Spinal Orthosis: _____

Additions: _____

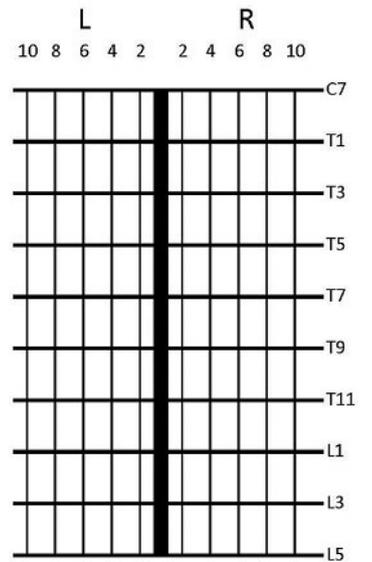
2. Head Support: _____

3. Foot-Ankle Support: _____

4. Upper Ext. Support: _____

J. Additional Information or Continued From Above:

Scoliosis Curvature:



TAMARACK Seating Measurement Sheet

Client: _____ Date: _____

Measurements by: _____

Due Dates: Trial _____ Final _____

Information from client/therapist/other relevant to seating:

(skin condition, range of motion, contractures, spasticity, etc.)

Wheel Chair:

Brand: _____ Type: _____

More than one wheel chair used? Yes / No

Armrests: fixed / removeable / height adjustable / desk length
standard length / other: _____

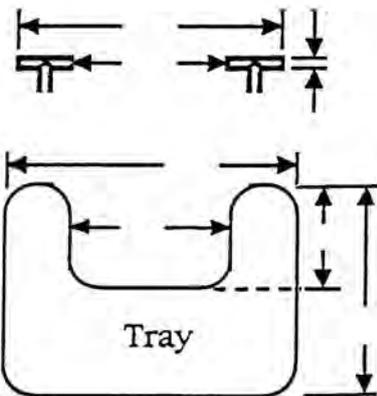
Footrests: swing away / fixed / elevating
other: _____

Seat Construction:

SSO USSO Firm Seat Firm Back RoHo Plat.

Needed Components:

- Head rest _____
- Lateral Thoracic Support _____
- Anterior Thor. Support _____" X _____"
- Extra Depth _____
- Increased Biangle _____
- Pelvic Belt _____
- Pelvic Bolster _____
- Pommel _____
- Foot Rest _____
- Color: _____ vinyl _____ rub.
- Other: _____

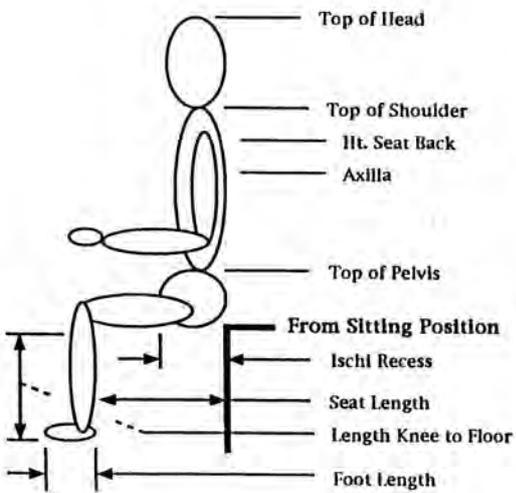


Appendix A

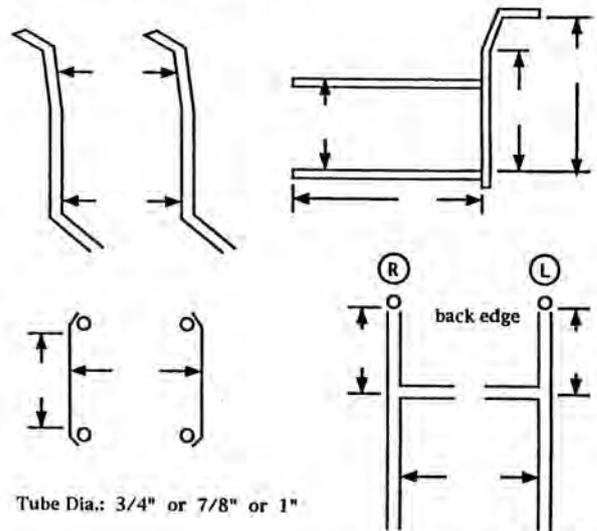
Measurements:

Taken while seated recumbent

- _____ " trochanters (hips flexed, seated)
- _____ " distal thighs (L-L)
- _____ " waist
- _____ " mid-thorax
- _____ " axilla
- _____ " A - P mid-thorax
- _____ " ASIS to ASIS



Chair Measurements:



Notes:

Appendix B

Gillette SSO Fabrication and Fitting

The initial step in fabrication is to obtain an impression of all necessary support surfaces in the best possible patient alignment for sitting. Figure B1 is a lateral view diagram of the casting fixture indicating the principle support forces needed to achieve optimal sitting posture in the sagittal plane. A parent or trusted caregiver should be in attendance near the patient's head. The patient's shoulders are abducted to clear the thoracic lateral surfaces up to the axillae. See figure B2. This type of casting support allows the orthotist to clearly see the full trunk alignment and have access to landmark all posterior and lateral surfaces prior to obtaining the impression or cast. See figure B3. The horizontal trunk alignment eliminates the collapsing effect of gravity during this procedure.



[Fig B1](#)



[Fig B2](#)

Most children with relatively severe CP have a strong tendency to extend at the hips. Passive hip flexion to between 95° and 100° usually results in a very marked relaxation of hip extensor tone. In fact, that degree of hip flexion often tends to relax the patient's upper body tone. Relaxation and control of the hip reflex while taking the impression/cast requires a waist belt, a knee support and a casting assistant. The waist belt passes around the back of the patient, through a wide longitudinal slot. Both ends are anchored to the underside of the casting frame. This keeps the waist snug to the frame while the height of the knee support is adjusted to create the desired hip flexion and pelvic alignment. When this is achieved, the pelvis and trunk may be teased into optimum coronal alignment.



[Fig B3](#)



[Fig B4](#)

When the desired body positioning is attained and land marking is done, as in figure B3, the cast or impression is captured. Casting may be done with bandages or dilatation (bead bag and vacuum) molding. See figure B4. The dilatation method is quicker than using plaster splints and so is tolerated more easily by some patients. After the positive model as seen in figure B5 is obtained from the cast or dilatation impression, the orthotist performs the usual bony relief and shaping to accommodate bony prominences. See figure B6. Extra space is provided on each side of the pelvis for pads that will be thinned and eventually removed when the SSO is made for a growing child.



[Fig B5](#)



[Fig B6](#)

Polypropylene thermoplastic sheet, about 6mm thick is preferred for creation of the SSO shell using a drape and vacuum-assist molding process. Polypropylene material has an adequate level of rigidity but can easily be modified with heat, if necessary, during fitting and for growth modifications. The SSO shell is embedded and bonded into a lightweight firm foam base that is sized to fit the patient's wheelchair. See figure B7. Another approach is to mount the shell to a flat lightweight base by means of metal bars or wood blocks at each of the four corners.



[Fig B7](#)

Sitting support challenges sometimes include severe hamstring contractures pulling the patient's knees into acute flexion. This effect is accentuated when the patient's hips are flexed to the degree required for the desired sitting posture. In such cases the knees must be allowed more than 90° of flexion to prevent knee flexion from pulling the hips forward out of their intended position in the shell. This should be assessed supine on a mat before SSO casting has begun. The needed extra knee flexion must be allowed during casting and can be accommodated by under-beveling the SSO base and recessing the footrest. See figure B8.



[Fig B8](#)

The series of diagrams in figures B9, B10 and B11 illustrate why the SSO often must be recessed down and

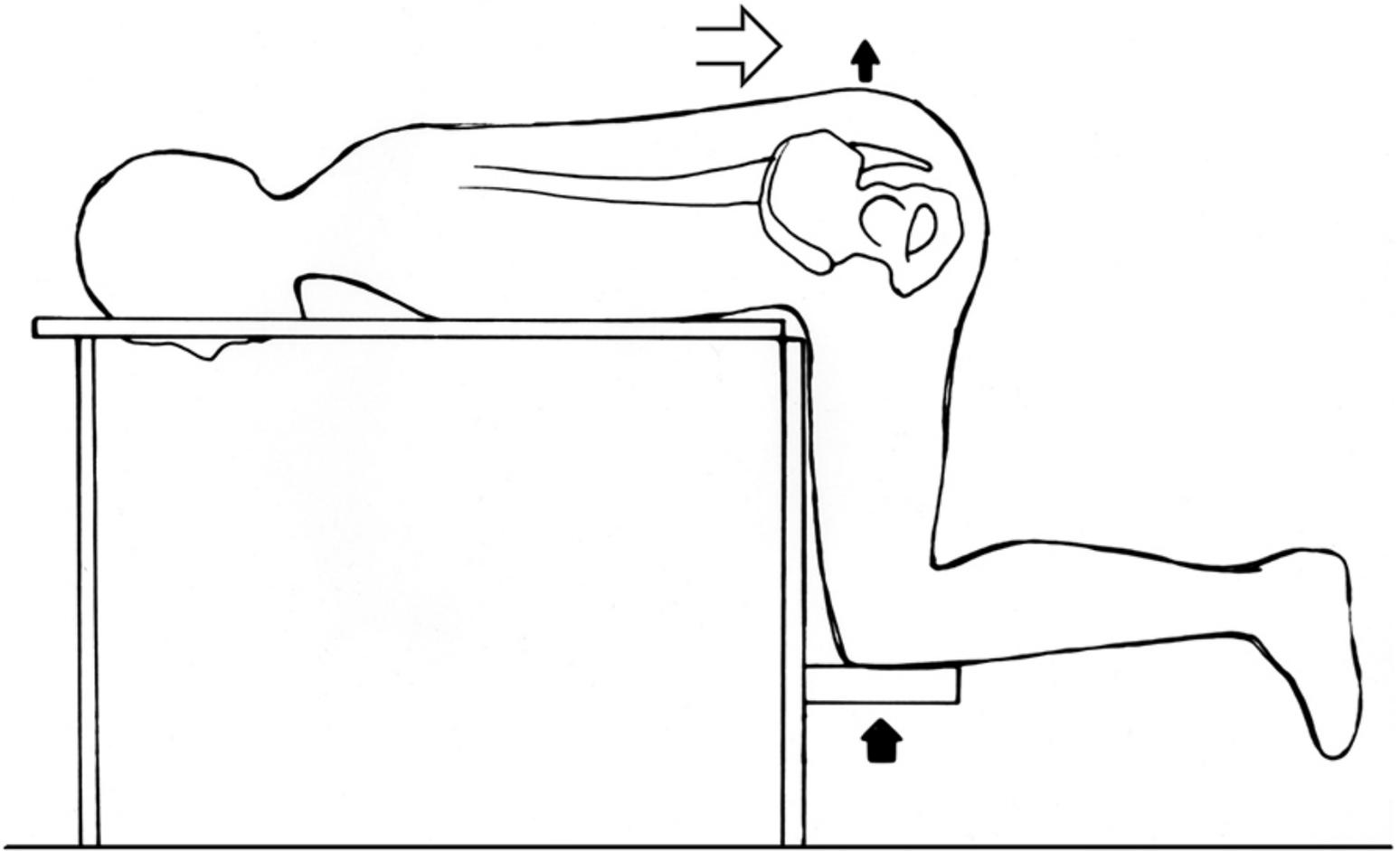


Fig B1

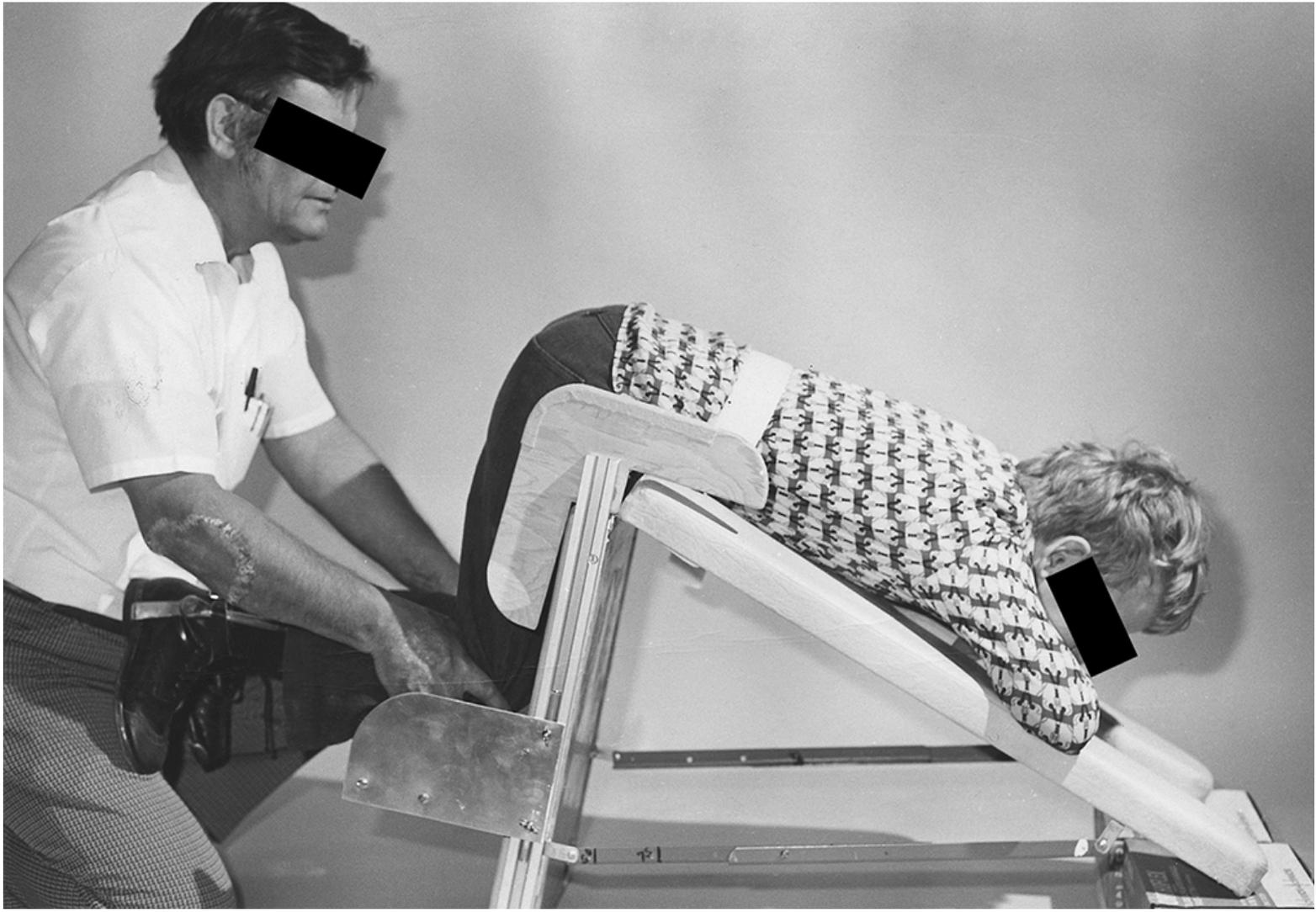


Fig B2



Fig B3



Fig B4



Fig B5

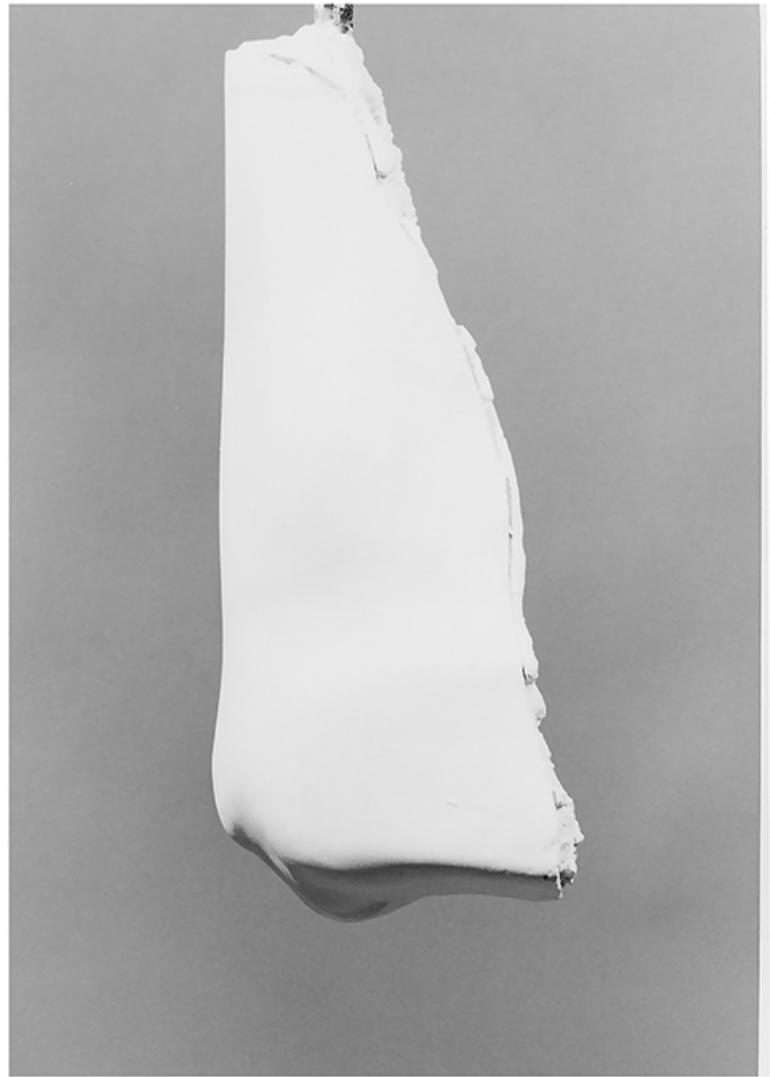


Fig B6



Fig B7

Appendix B

back into the wheelchair. Figure B9 is a lateral view of the familiar posture often observed in CP where adequate sitting support is lacking. The patient's weight is pressing into a sagging seat bottom and backrest. These factors locate the patient's CG relatively low in the chair. The one good thing about this is that his shoulder position gives his hands good access to the drive wheel rims. The final result of better sitting support for that patient may be that he then has limited hand access to the wheel rim. See figure B10. This last point is important to the few patients with severe CP who are able to power a manual wheelchair and to virtually all people with paraplegic and low quadriplegic SCI. The other thing apparent in figure B10 is that the CG of the person in his wheelchair has been significantly elevated, decreasing overall stability. Special adaptations to the seating system and the wheelchair will allow the patient to sink down and back in the wheelchair. Appendix C, figures C19 and C20 illustrate how to adapt the SSO base and the wheelchair. This will improve both hand-to-wheel access and stability of the patient and wheelchair unit. See figure B11.



[Fig B9](#)



[Fig B10](#)



[Fig B11](#)

In all cases, the seating system is only partially fabricated before the first trial fitting. During the first trial fitting, trim lines and areas of supportive contact are examined and changed accordingly. Not all of the inner surfaces of a seat should be in contact with the client. Some areas should be without contact to allow airflow and corrective space. From that point onward, the trial fitting focuses more and more attention on observing and getting feedback from the client and caregivers about comfort and function. Throughout the fitting process design participation by the client and all others in his daily life is encouraged. Depending on the difficulty of the challenges, the severity of the client's impairment and the level of functional expectations, the fitting process may need more than one visit. In some cases it is advisable for the patient to take the seating home and use it for a week or so before the configuration is finalized and the system is upholstered.

Over months and years, as horizons expand and change for the client, new issues, factors and opportunities are discovered. These discoveries will guide the way to design refinements.

During the fitting process, a significant amount of time is devoted to educating the client and caregivers in the proper use of the orthosis, how to recognize problems, and when it is appropriate to contact the provider. The client's and caregivers are in the best position to notice that needs are changing. Caregivers should be informed that the seating specialists welcome feedback. They should be conscientious about notifying the provider about changes and about the need for maintenance or repair. The client, if a child, must return with the seating orthosis on a semi-annual basis and adults should return annually. The majority of SSOs are provided to children and it may seem like a large investment for a rapidly growing patient, however, a skilled technician easily accomplishes modifications for thoracic and pelvic growth, mentioned earlier. Accommodating femur growth is a simple process of lengthening the seat base.

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

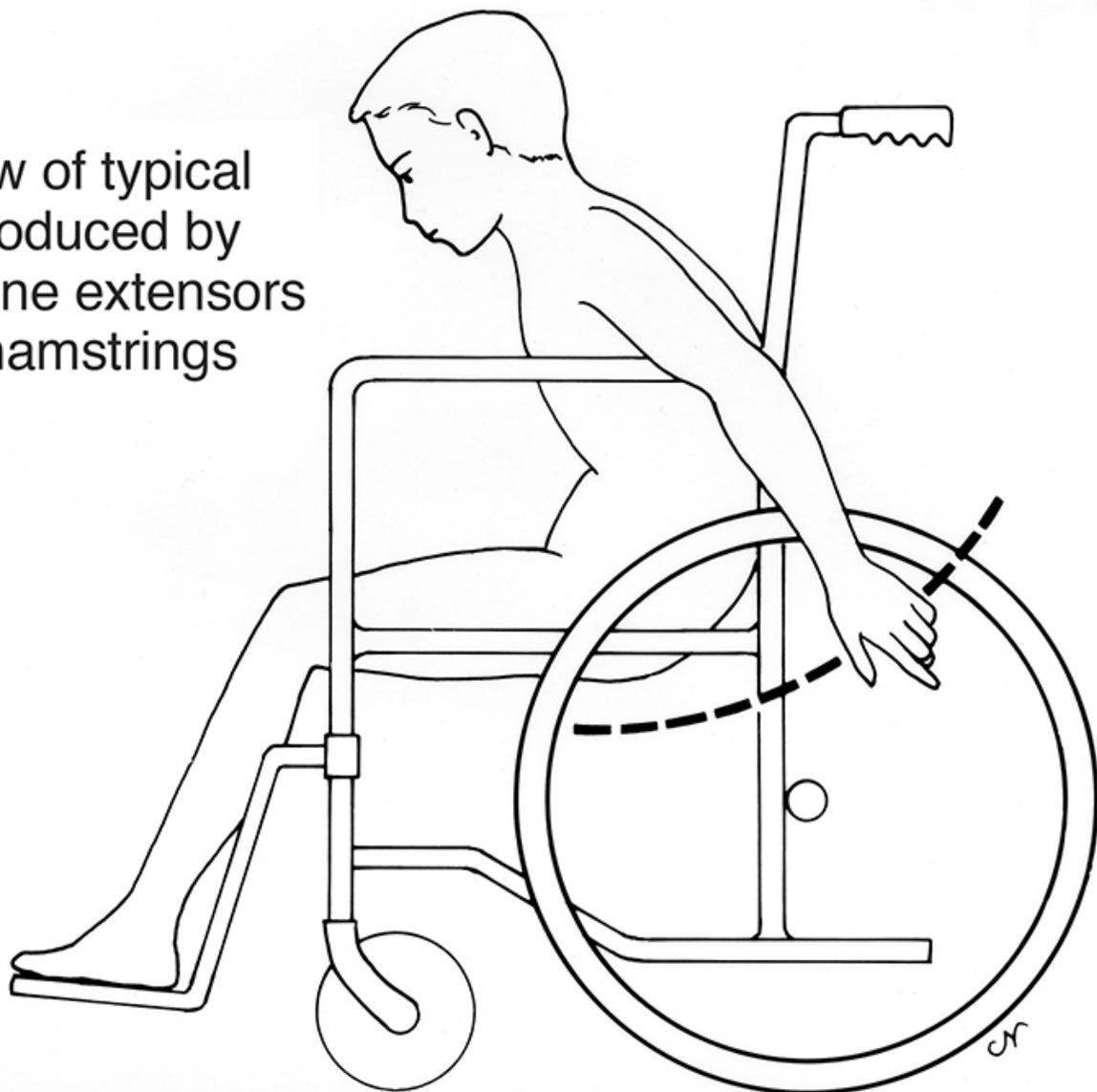


Fig B9

Patient positioned
too high and forward

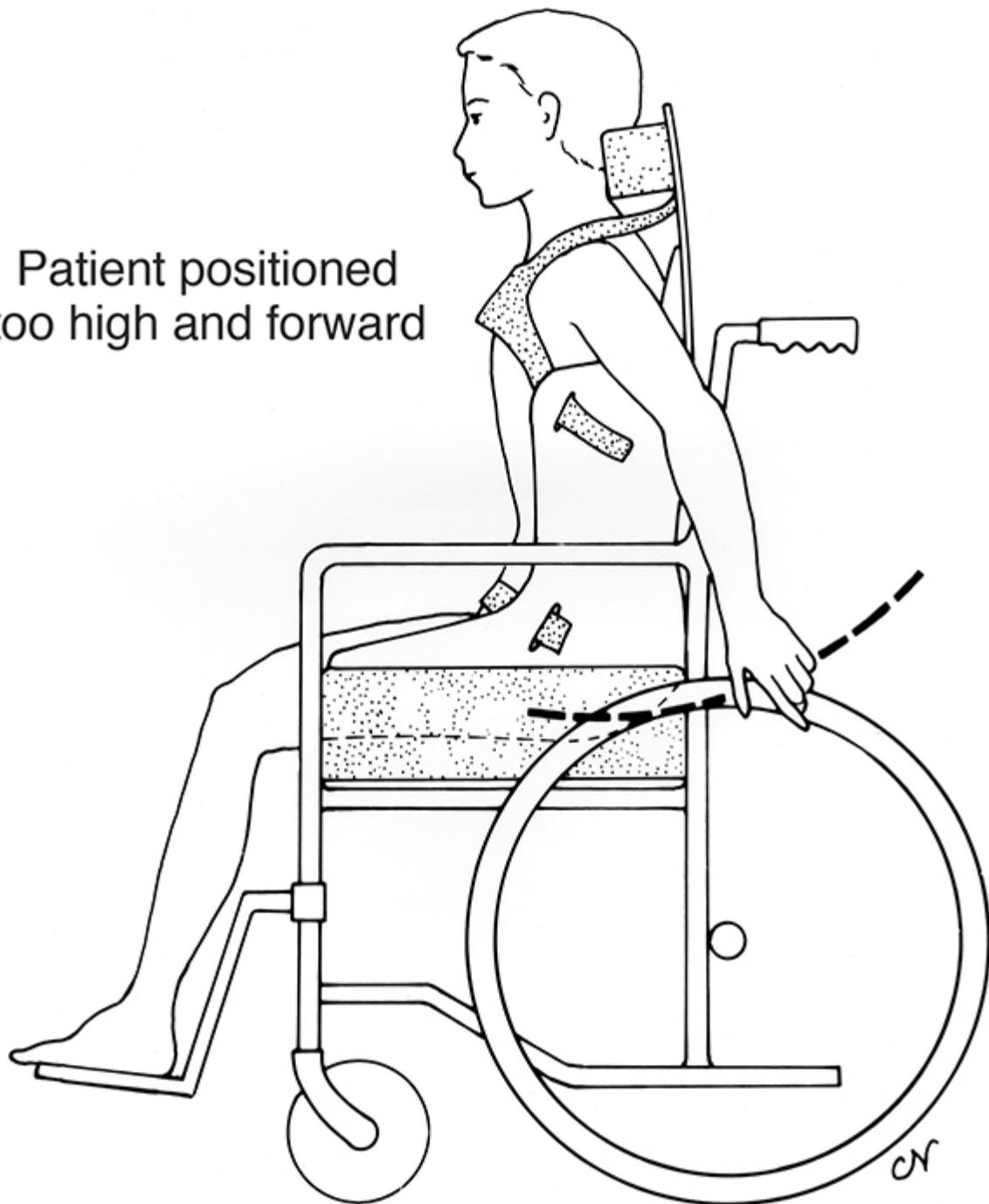


Fig B10

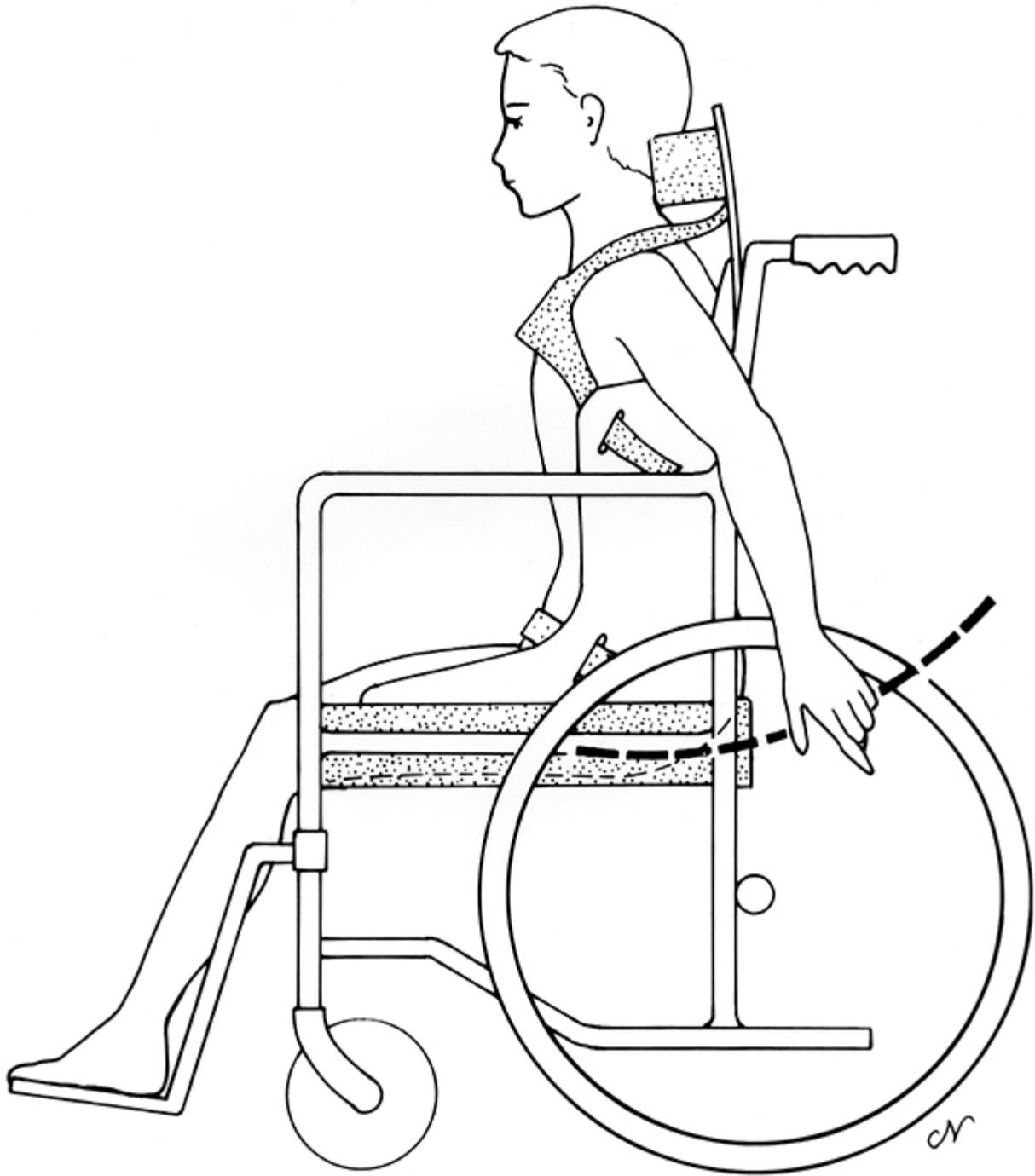
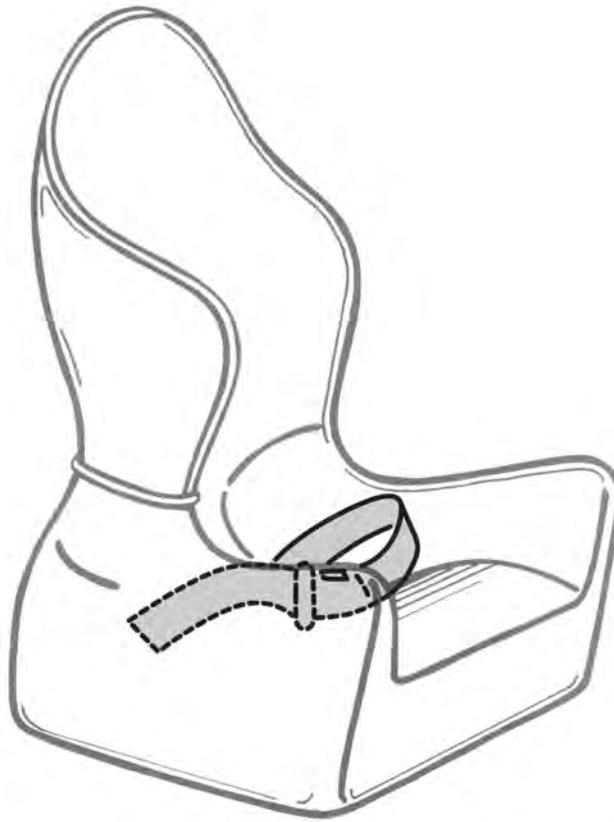


Fig B11

Appendix C

Illustrated Prescriptive and Design Guide

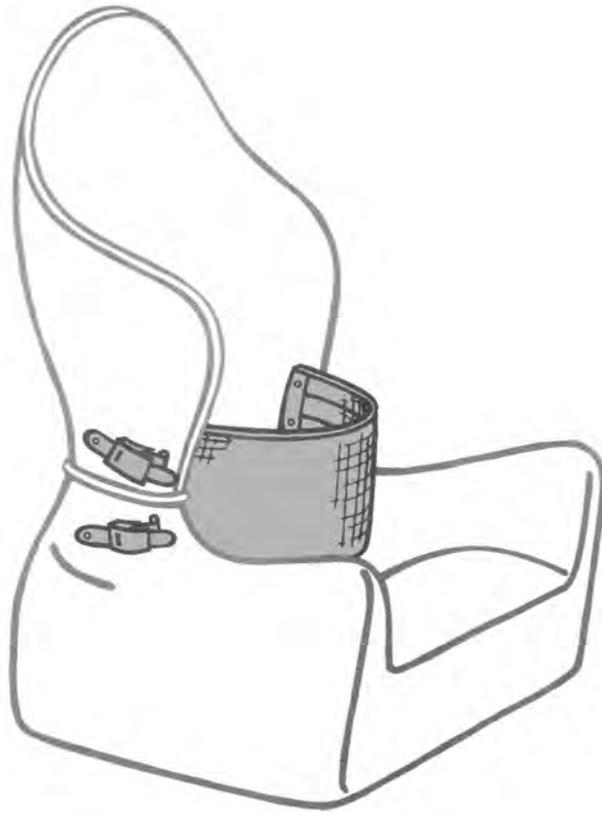
Appendix C



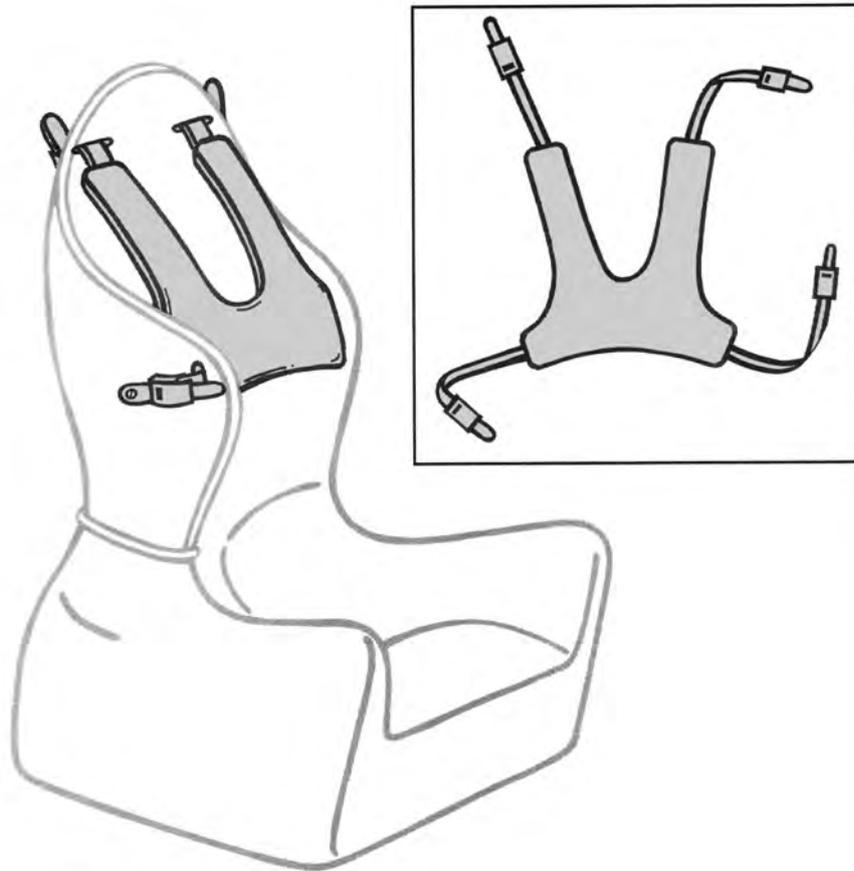
C1. Gillette SSO

For diagnosis of Cerebral Palsy, Spastic Quadriplegia and other conditions where the client has minimal voluntary sitting control and skin breakdown risks are low but muscle tone reflex patterns and orthopedic deformities are greater than moderate.

Appendix C



C2. Abdominal panel
For control of hyperlordosis



C3. Upper thoracic support vest

For control of thoracic hyperkyphosis

- Top center should be below sternum
- Bottom border across chest should be slightly loose
- Allows free arm function

Appendix C



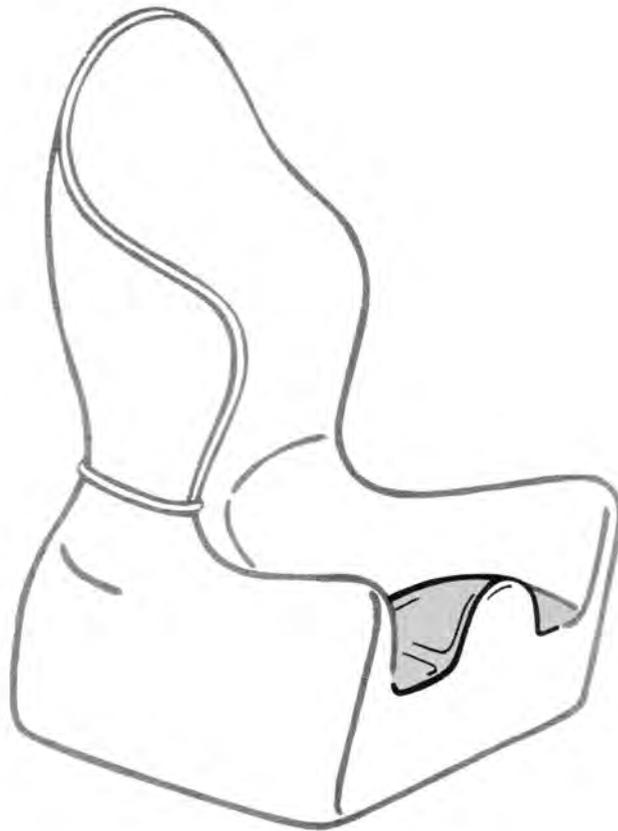
- C4. Upper thoracic support shoulder straps
For control of thoracic hyperkyphosis
- Will impede arm function at shoulder



C5. Bandolier style anterior support

For control of forward lean

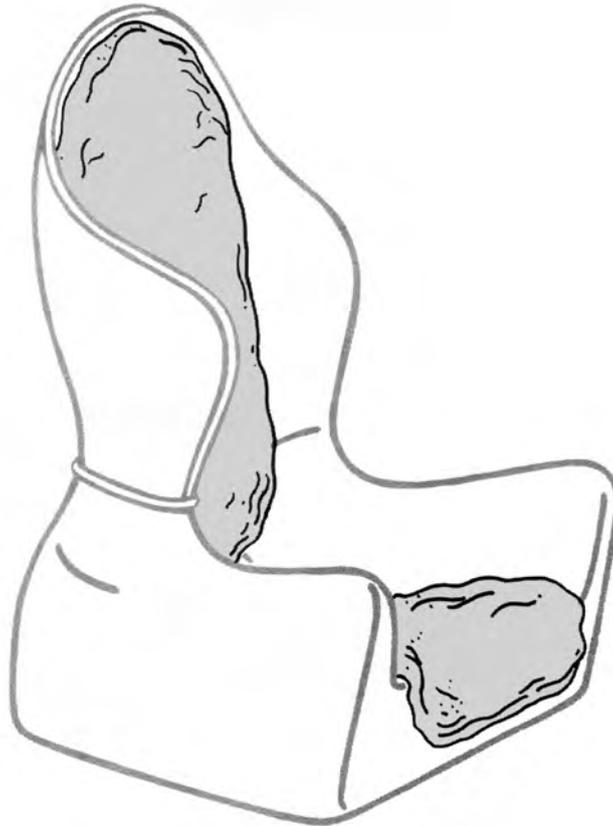
- Easy adjustment of client's forward lean
- Very useful for boys with MD and some people with quadriplegic level SCI



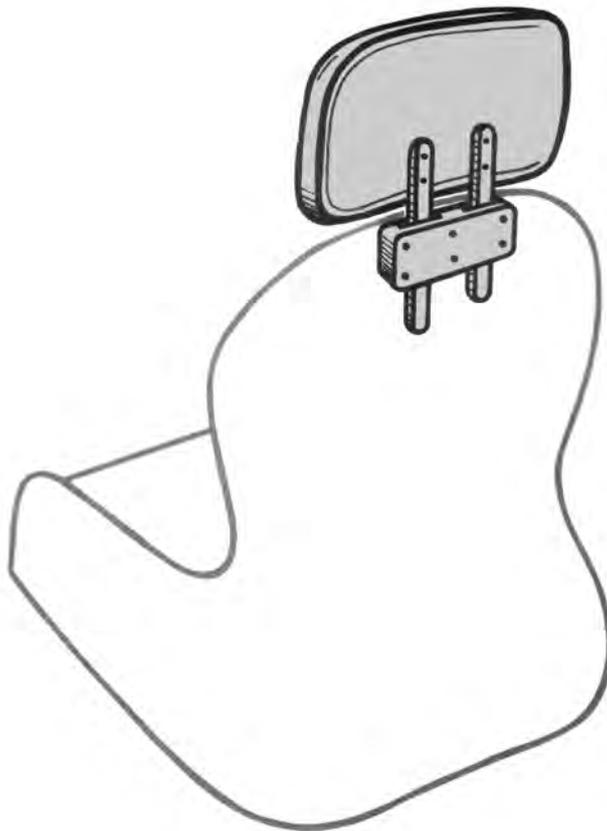
C6. Pommel

For control of hip adduction

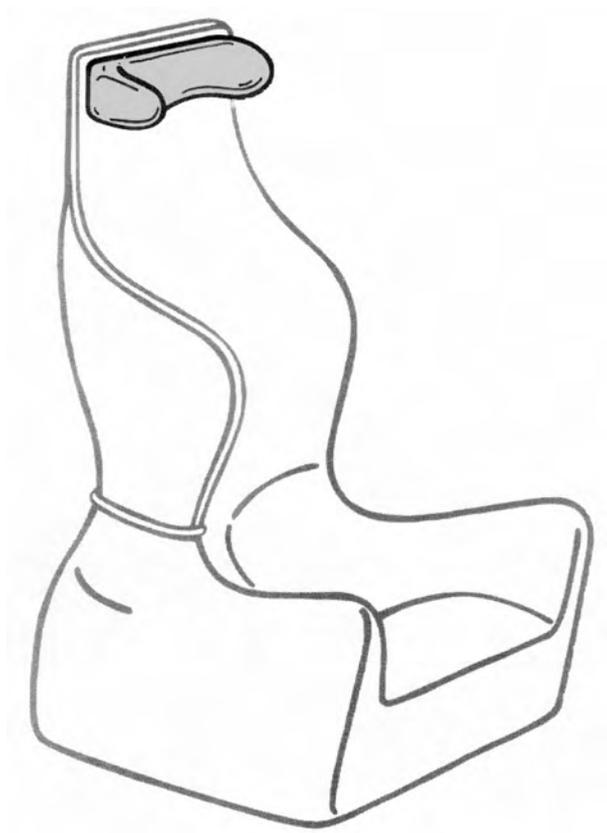
- If a fixed pommel will cause a transfer/donning barrier, it should be removable



C7. Fleece Lining
For heat and moisture dissipation

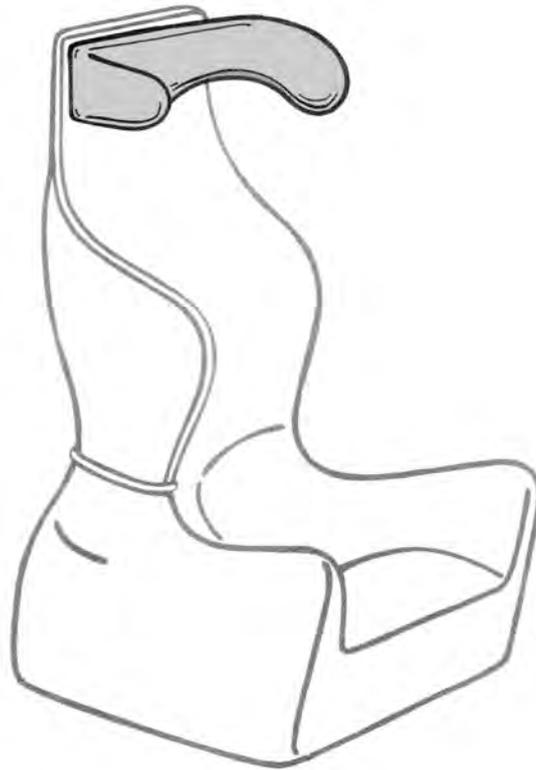


C8. Removable cranio-cervical support
For when support is not always desired.



C9. Occipital cradle cranio-cervical support
For control of cervical extension or to rest weak cervical flexors

Appendix C



C10. Occipital cradle with unilateral flexion control bolster

For when left or right cervical flexors require help to maintain client's head in midline

- Bilateral bolsters when necessary



C11. Postero-lateral cranio-cervical support
For control of forceful involuntary lateral neck flexion



C12. Full cranio-cervical support

For control of lateral and forward cervical flexion

- Effective against gravity, cannot control spastic flexion

Appendix C

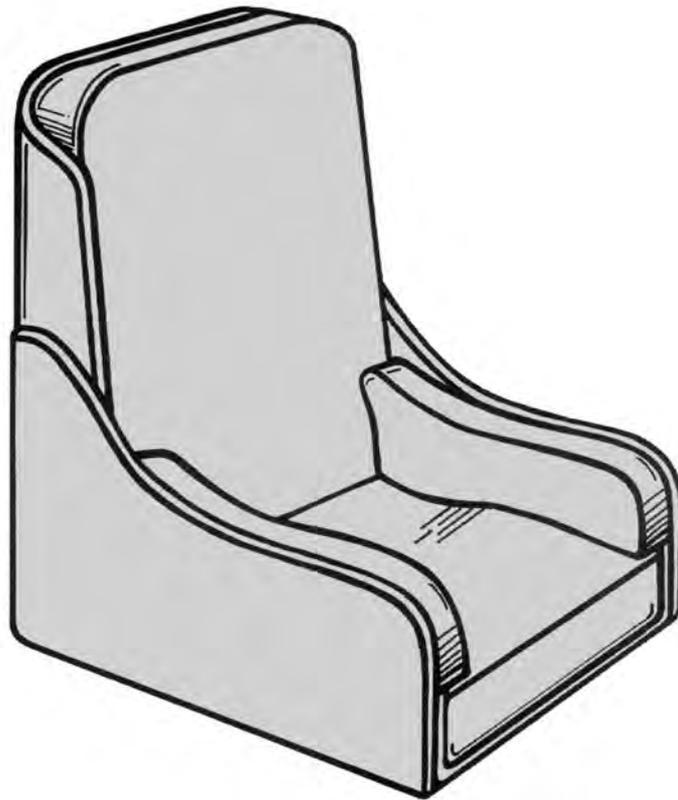


- C13. Firm, padded wheelchair cushion
For improved comfort for short term or more active patients with full sensation.



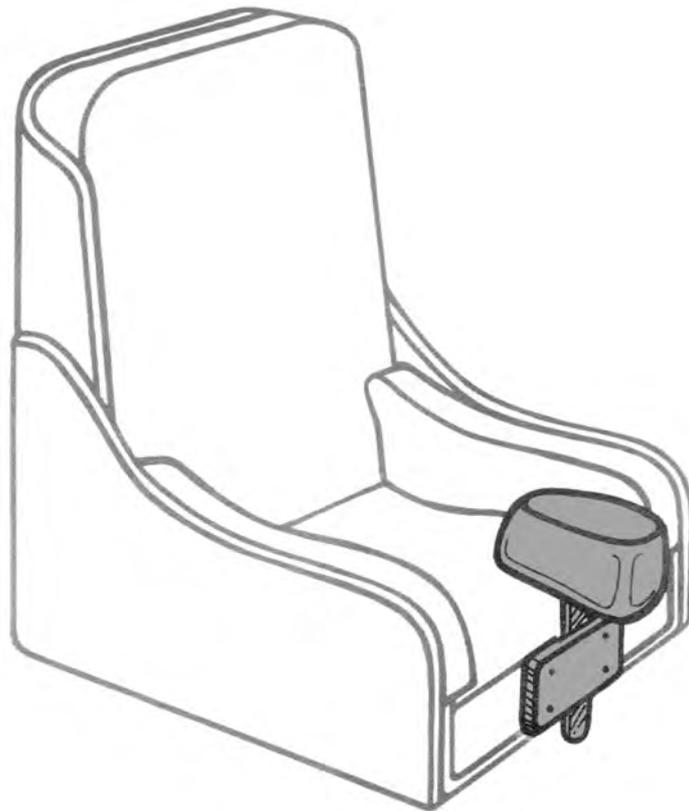
C14. Custom contoured and padded wheelchair cushion
For pressure, friction and posture management.

- Most often prescribed for clients with paraplegic and low quadriplegic SCI

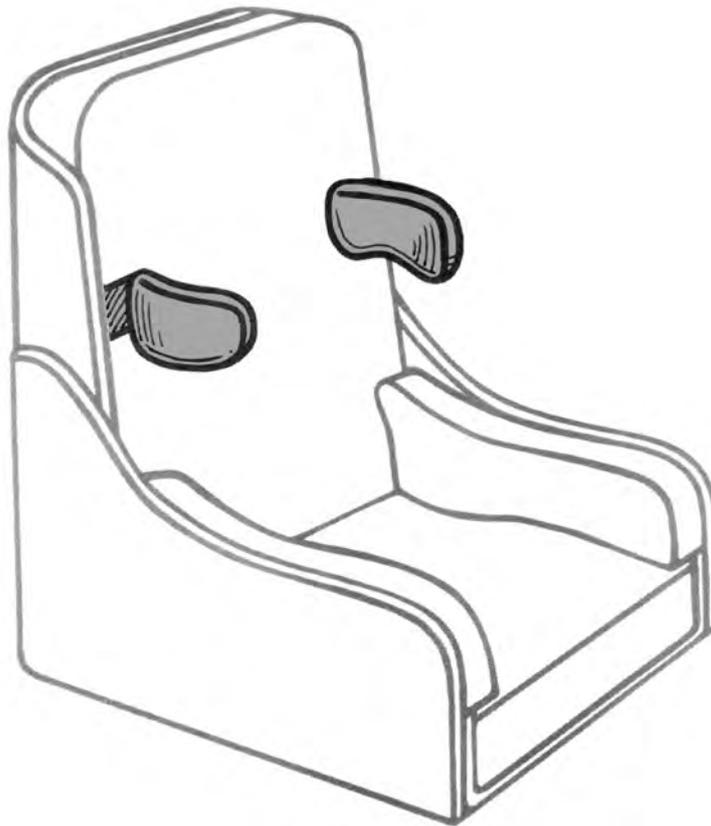


- C15. Rectilinear seat orthosis (RSO) with removable upholstered components
For neuromuscular conditions, mainly CP where the client has minimal voluntary sitting control and minimal hip and spine deformities.

Appendix C



C16. Pommel addition to RSO
For hip adduction control

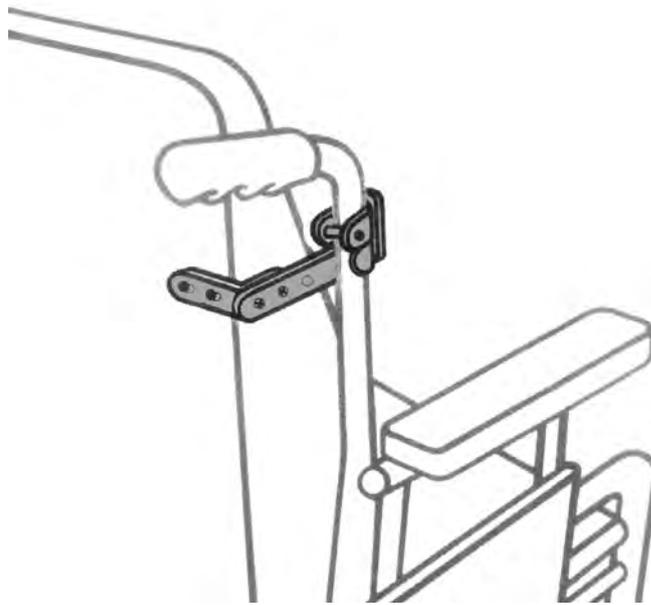


C17. Bilateral thoracic bolsters addition to RSO

For thoracic centering

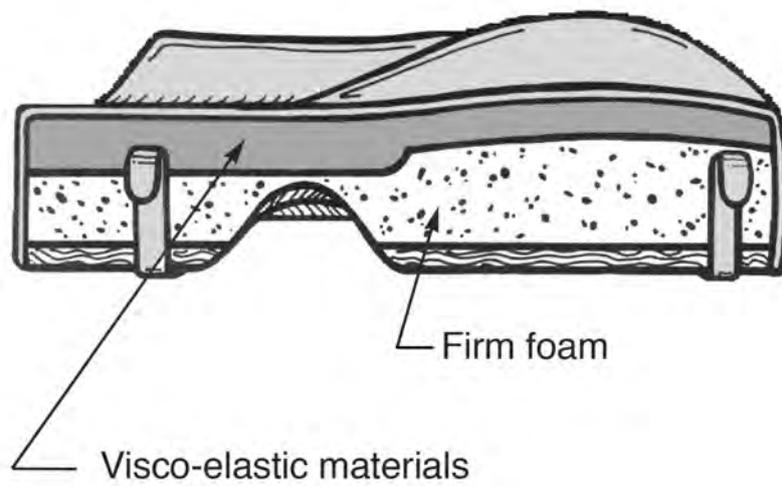
- Bolsters may be installed one at axillary level and the other at a low thoracic level to provide some control of flexible, collapsing thoracolumbar scoliosis.

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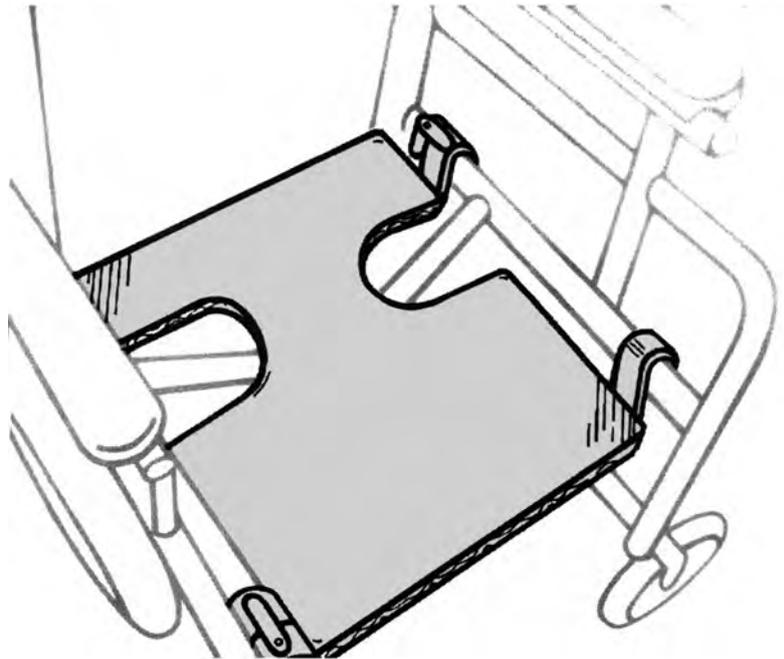
C18. Hardware to posteriorly recess seat components in wheelchair (very similar to hardware for downward recessing a seat platform in the wheelchair)
For increasing stability and/or hand access to drive wheels

Appendix C



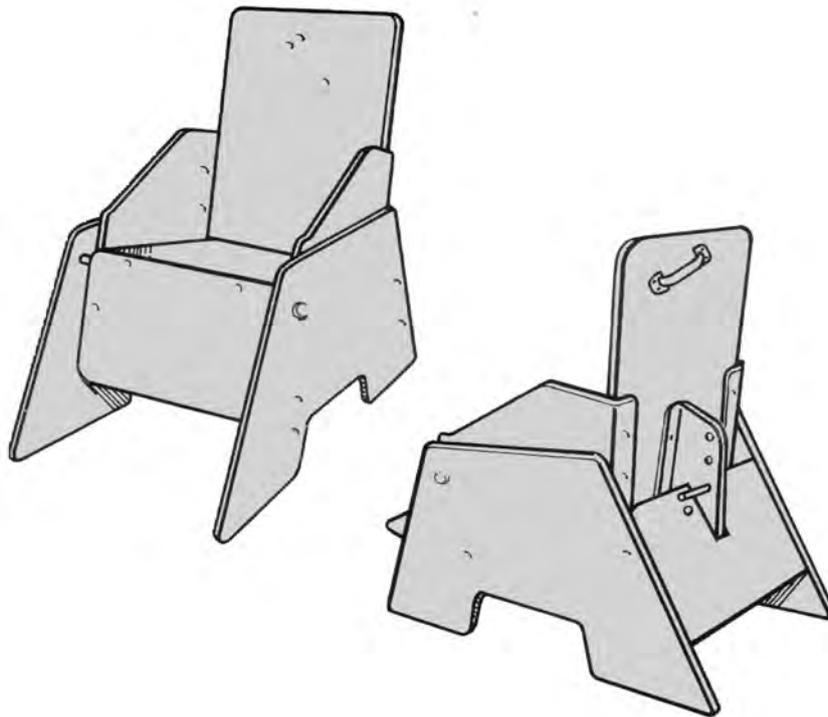
C19. Seat base modification to fit around folding wheelchair “x” bars
For increasing stability and/or hand-to-wheel access

Appendix C



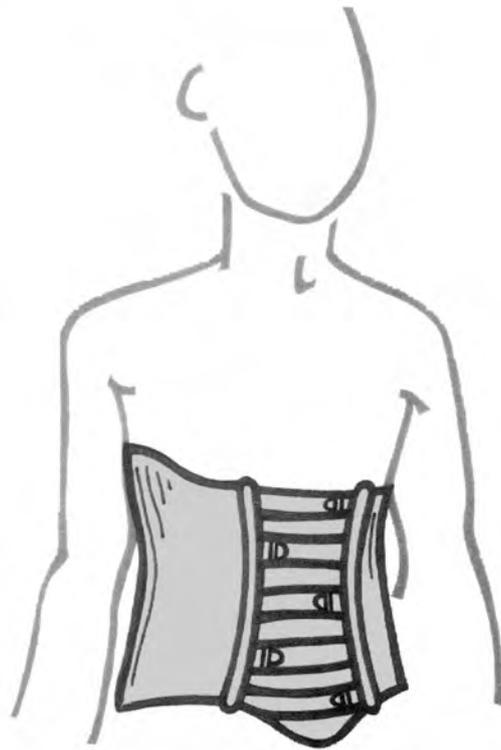
- C20. Cushion recess platform in folding wheelchair
For stability and drive wheel access or to allow some clients to propel with feet.

Appendix C



C21. Floor base to seat patient close to floor

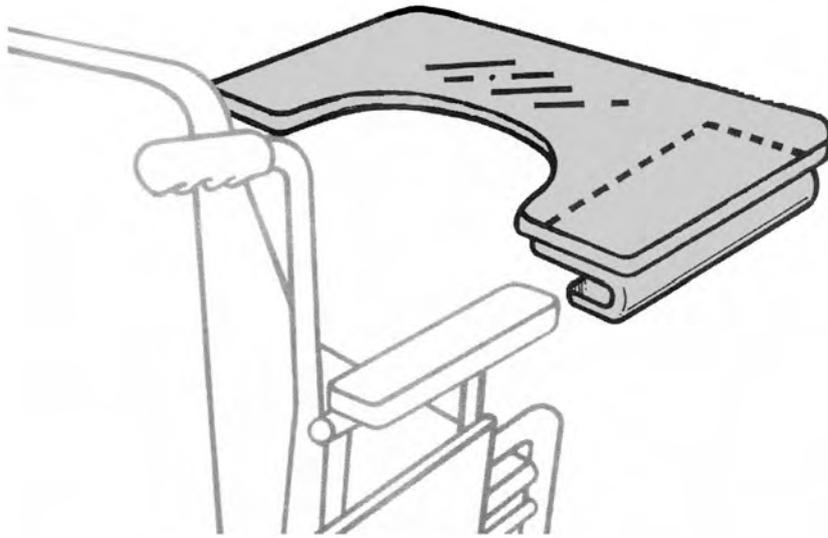
For allowing small children, usually less than 8 years, to be near the floor with playmates and other children during play times.



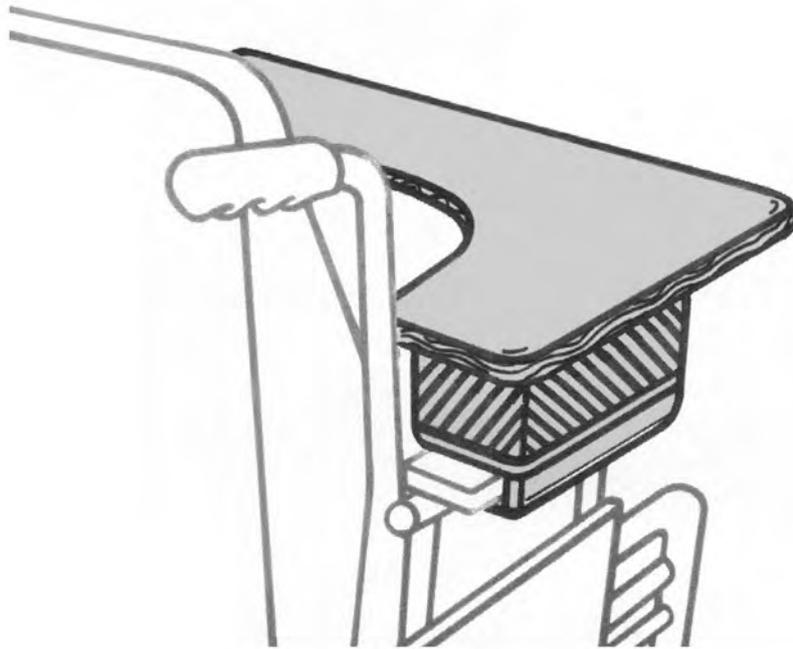
C22. Corset Thoraco lumbo-sacral orthosis (TLSO) made of fabric panels or molded leather to substitute for flaccid abdominal muscles.

For resistance to collapsing spine deformity and/or for improved pulmonary function

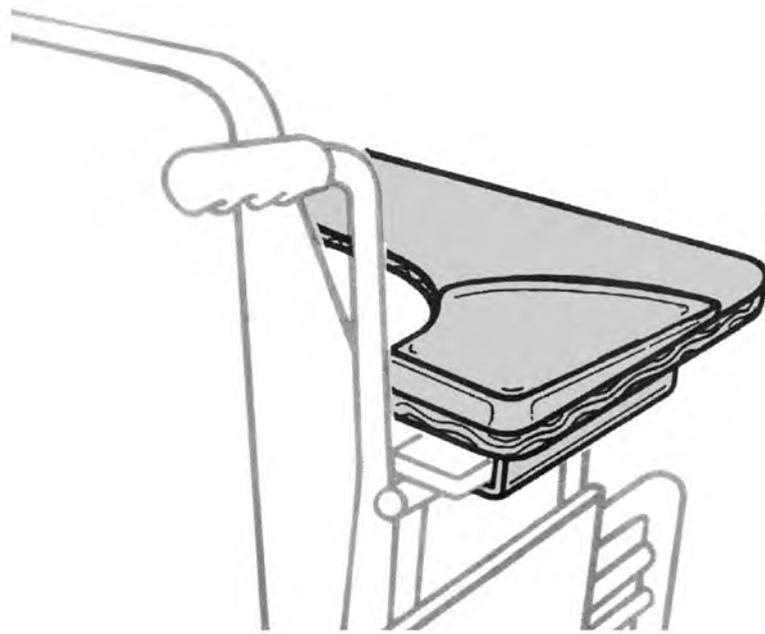
- May be tailored from measurements or, when necessary, from panels fit to plaster model



- C23. Lap tray with adaptations to slide onto wheelchair armrests.
For a work, study or communication surface prescribed for a variety of neuromuscular patients who use wheelchairs.

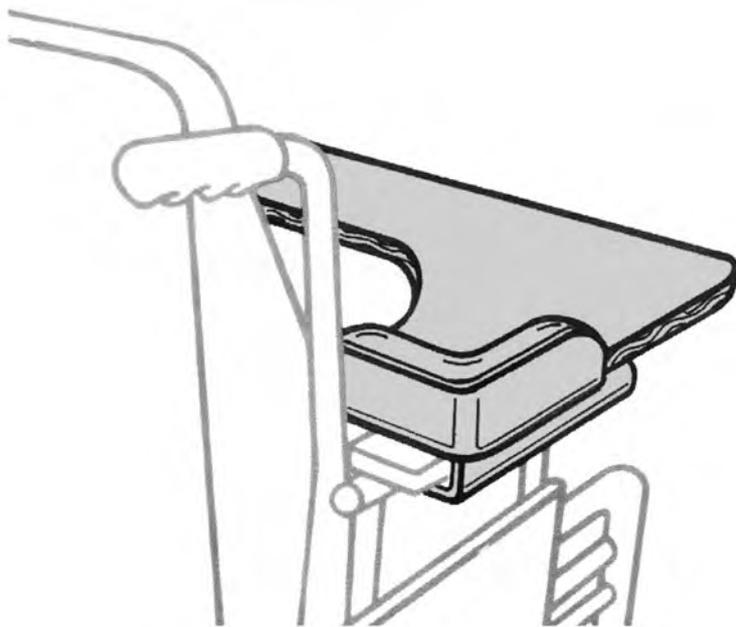


- C24. Elevation block between lap tray and armrest channels
For elevating the lap tray to a height which is optimum for patient arm support and/or other function.



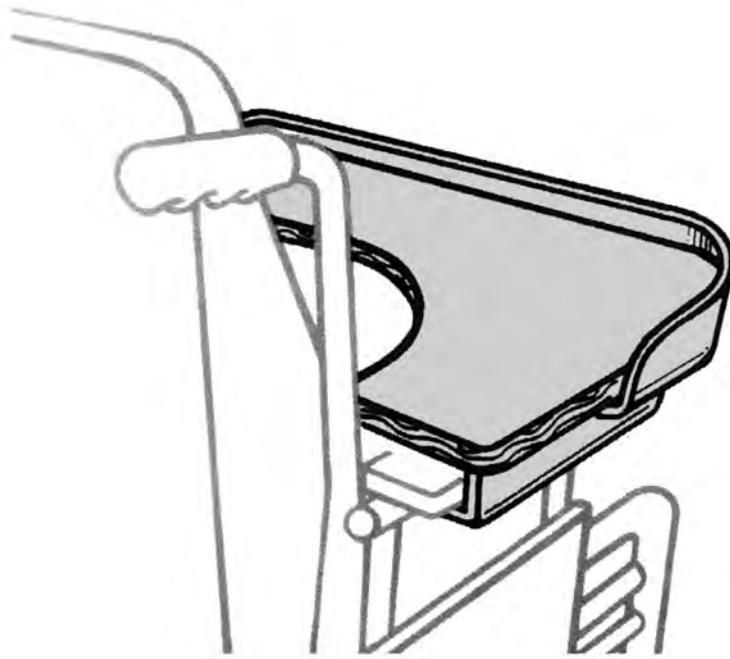
- C25. Padded elbow and forearm area on lap tray.
For reducing peak elbow pressure and increasing comfort when patients lean forward, bearing some upper body weight through their arms.

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C26. Padded blocks at posterior elbows
For blocking involuntary, forceful shoulder extension

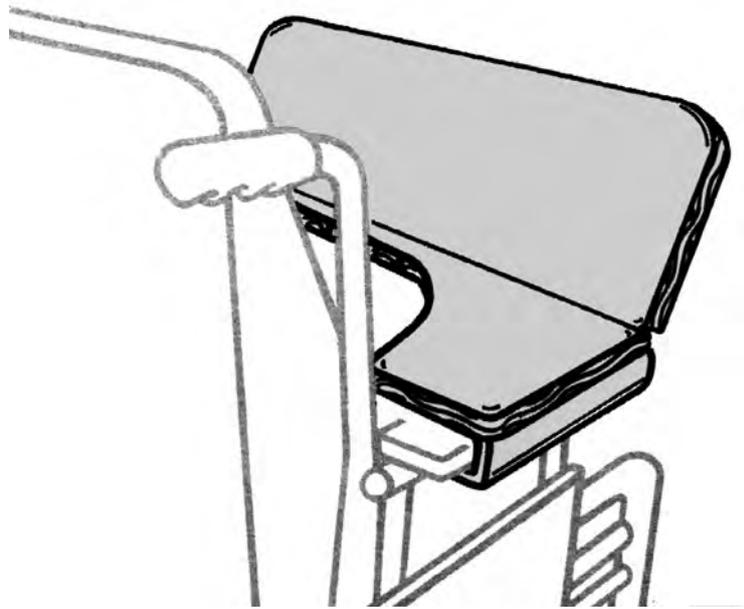
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C27. Object containment rim on lap tray

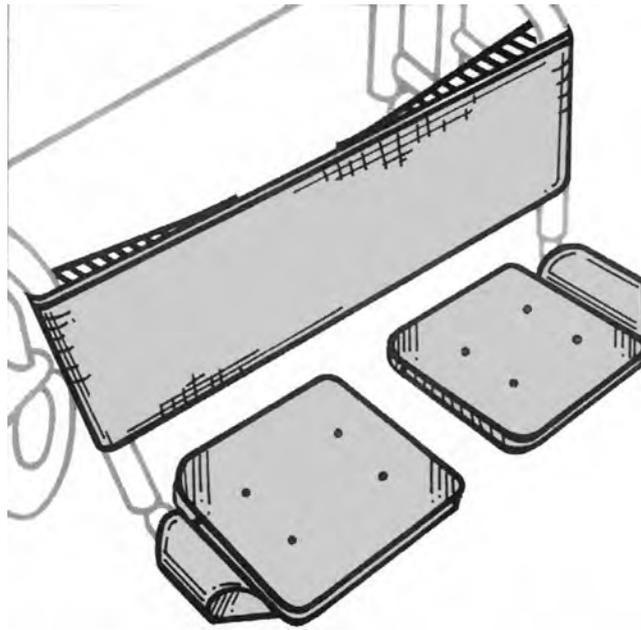
For when uncontrolled upper limb movements tend to push items over the edge of the lap tray.

Appendix C



- C28. Lap tray hinged to create easel effect
For improving sight and hand access as necessary for reading, painting, communication devices, etc.

Appendix C



C29. Calf support panel

For prevention of foot injury, which may happen when, feet become lodged posterior and under the footrests as the wheelchair is moved.