

Seating and Wheelchair Prescription

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OBJECTIVES

After reading this chapter, the reader will be able to:

- List the fundamental components of “seating”
- Recognize the features of an ultralight manual wheelchair, compare frame styles, and understand configuration options
- Understand the different power mobility options for base and seat selections
- Discuss the benefits and challenges for use of power mobility
- Discuss common theories of cushion design for skin protection and postural support
- Discuss the interaction between components of the seating system
- Describe the required components of a postural examination for seating purposes
- Discuss the influence of seated posture on dynamic function
- Justify the need for selected/prescribed seating system components
- Be able to defend time spent in seating planning and intervention as therapeutic time for the client

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Introduction

Seating is the foundation for optimal outcomes in the spinal cord-injured population, especially for those who use wheelchairs for full-time mobility. There is an intimate and obligatory relationship between the posture of a paralyzed body and the support provided from the seating system. Postural alignment directly impacts respiration, swallowing, speech, skin, and musculoskeletal health and function. Posture may also affect the body image of an individual and feelings of self-worth and therefore participation in the community after spinal cord injury (SCI). The multi-factorial influence of posture on health outcomes makes seating a premier concern for early intervention and constant vigilant monitoring throughout the injured person's lifetime.

Understanding the interactions of the seating system and the resulting postural alignment requires careful integration of information from the physical therapy examination and an understanding of the potential, as well as the constraints, of the equipment. Specifying an orthotic seating system is a specialty skill. It provides therapeutic benefits for the client. The therapist must evaluate the impact of selected parameters of a seating system and any adjustments made and must understand the effect on the client/user. Seating requires critical thinking, analysis, and integration of knowledge by the therapist. The actual mechanics of seating system configuration changes may be delegated to qualified support personnel, but the evaluation, specification, and fitting should never be relegated to anyone other than a skilled seating therapist (i.e., physical or occupational therapist).

In this chapter, the concepts of the evaluation for and prescription of a therapeutic system will be described, and a strategy for defining the specifications will be developed for a client. However, an exhaustive review of all available products is beyond the scope of this text and the fact is that specific device-related information would soon be outdated. More importantly, seating for

the client with SCI needs to be individualized based on examinations, assessments, and interventions. There is no such thing as the "best wheelchair" or the "best cushion," although there may well be an optimal wheelchair configuration or cushion for the *individual* in question. Upon completion of this chapter, the reader will understand seating system selection and configuration for the client with SCI in order to optimize seated posture: The goal of optimal seated posture is to promote maximum independence via the achievement of functional skills, comfort, and skin health.

An explicit overarching message in this chapter is that seating *is* therapy. For the population of individuals with SCI, seating is a vital therapy, and the process of thoughtful seating should begin even before the new rehabilitation client gets out of the intensive care unit bed. A properly selected and set up wheelchair as the *first* wheelchair experience can set the stage for a successful rehabilitation. Early use of an appropriate system promotes overall health, mobility skill achievement, and the early success of the patient. An appropriate seating system is also important as a preventive strategy. Appropriate wheelchair setup and optimized posture will decrease the musculoskeletal stresses associated with prolonged sitting and wheelchair propulsion as well as protect against skin breakdown. Quality equipment, which optimizes functional ability, improves overall health and protects against systemic pathologies such as cardiovascular impairment and obesity. Self-efficacy in community mobility skills is also likely to improve a wheelchair user's mental health status.

The following is an overview of current evidence relative to seating and wheelchairs for the client with SCI. Research relative to postural alignment is limited, especially studies specifically addressing seated posture in individuals with SCI. Evidence is available to support the hypothesis that posterior pelvic tilt and spinal flexion posture correlates with negative sequelae.¹⁻⁵ Research concerning manual wheelchairs has been targeted toward durability, configuration for stability, and configuration

for propulsion. In general, the literature supports the use of high-strength, lightweight materials for manual wheelchairs and a forward position of the rear wheel to improve the propulsion mechanics.⁶ Published research pertaining to power wheelchairs is extremely limited. While high-end power bases have been shown to be most durable, there is no published research to indicate a preferred drive wheel position. Some research has been completed to define optimal power seat functions and configuration relative to skin integrity at the sitting surface. With the many variables associated with cushion materials, design, and properties, published research supports individualized cushion selection for the client with SCI.

Fundamentally, there are three primary components of a seating prescription for the client with SCI: (1) the mobility base (the wheelchair, either power or manual); (2) the seating interface (the cushion and backrest); and (3) the size and configuration of the equipment. The final component is perhaps the most important. The actual *size and configuration of the equipment* is the feature that will provide the optimal stability and mobility for the spinal cord-injured person. The correct size and configuration of the equipment is derived from a systematic evaluation of the client with particular attention to anatomical measurements. The seating system is literally built upon the foundation of the size and configuration of the wheelchair. If the seat depth is longer than the anatomical thigh length, then the individual will not be able to sit erect. Similarly, if the available hip range of motion does not match the angle between the seat and backrest, then optimal pelvic positioning will not be achieved. There are also three distinct but interrelated goals for a seating system: postural goals, mobility goals, and functional goals. To a large extent, the overall health outcomes of the individual, including musculoskeletal health, respiratory function, and skin integrity, will depend on how well these goals are addressed.

Alignment and Musculoskeletal Pain

In the general population, normal standing alignment is a "plumb-line posture," such that a plumb line will align the ear lobe, shoulder, hip, and knee. This alignment establishes the normal spinal curves. The plumb line posture is known to take the least muscular work to maintain.⁷ Essentially, this posture capitalizes on gravity to assist in the maintenance of posture, with the line of gravity passing just posterior to the hip and just anterior to the knee. Any deviation from this posture will increase the work of standing. Postural abnormalities are also known to be associated with pain. For instance, Greenfield⁸ found that forward head position is associated with shoulder pain. In a seminal manuscript, Keegan⁹ illustrated that optimal health of the lumbar spine is promoted with sitting postures as closely approximating those in standing as possible. Optimal posture, whether standing or sitting, is achieved when

the center of gravity is over the base of support. This posture requires the least amount of muscular work to maintain, and it is the posture from which it is the easiest to move.

Muscles function to support or move a joint. In general, if passive stability is insufficient, muscles will work harder to provide contractile support to maintain a joint in a given postural position. If postural support is lacking, the residual trunk and upper extremity muscles (superficial back muscles) work excessively in an attempt to stabilize. Muscles generally have a length at which they operate most efficiently. Muscles can be physiologically too short (active insufficient) or too long (passive insufficient). Muscles working outside of their optimal length are disadvantaged and tend to fatigue. Muscles also fall into physiologic categories: phasic muscles are best suited for short bursts of activity requiring high speed or force, while tonic muscles are best suited for prolonged, low-forces activities. Postural muscles are typically tonic muscles that work best in midrange or shortened length. In the condition of kyphosis, posterior postural muscles become overlengthened and ineffective.

Chronic poor posture negatively impacts the strength and balance of forces around the shoulder joint. A depleted muscle is one that is tapped of all glucose supply or working beyond its vascular capacity for refueling and waste removal; pain can arise from a depleted muscle. A muscle working excessively, beyond its capacity for force generation or at a frequency beyond its tolerance, can also be a source of pain. Mechanical pain in the musculoskeletal system can also be articular in origin. Alignment is critical for appropriate articular function; malalignment created by muscle imbalance can contribute to the creation of articular pain by not maintaining appropriate articular surface congruency. In the upper extremity, postural malalignment will create altered glenohumeral joint mechanics.

Alignment and Function

Appropriate seating is the platform for upper limb function. The shoulder and upper limb are designed for optimal mobility to facilitate hand placement in all dimensions. The upper limb articulates with the axial skeleton via the pectoral girdle. Muscles and ligaments largely suspend the pectoral girdle in order to allow maximal movement and flexibility. The only bony articulation between the trunk and upper limb is at the sternoclavicular joint. The glenohumeral joint (true shoulder) lacks bony constraint throughout the normal range of motion. This design is essential for upper limb mobility; however, stability through bony factors is minimal. Stability is established by the soft tissues (e.g., ligaments, capsule, labrum, muscles) and by alignment. End range stability is achieved when soft tissues, particularly the ligaments and capsule, are stretched to their physiologic limit. Dynamic stability

is achieved by concavity compression and glenohumeral balance in midranges of motion.¹⁰ Concavity compression is a mechanism in which the humeral head is compressed into the glenoid fossa by muscles (particularly the rotator cuff musculature), thereby resisting translational forces. Glenohumeral balance is a stabilizing mechanism in which the glenoid fossa (therefore the scapula) is positioned in the most stable position (i.e., so that the net humeral joint reaction force passes through the glenoid fossa). Because of the articulation to the axial skeleton via the sternoclavicular joint, the shoulder girdle is obligatory in its relationship to the spine. Spinal posture determines alignment and positioning of the scapula. Therefore, the resting lengths of the shoulder girdle musculature and the resulting biomechanical stability of the shoulder are dependent on spinal posture.

The spinal cord-injured population is unique not only in that they use their upper extremities for mobility and weight bearing, but that they are also paralyzed, significantly in the trunk and gluteal muscles, and they are seated. Individuals with significant truncal paralysis do not have normal trunk control against gravity. Compensatory strategies for absent trunk innervation include stabilization with the upper extremities and a C-sitting spinal posture.¹¹ A C-sitting posture is characterized by a posterior pelvic tilt and flexion of the lumbar and thoracic spine. C-sitting creates an overall shorter sitting posture and a tendency for a forward head posture. In a study assessing sitting stability with reaching task, Seelen and Vuurman¹² noted that persons with SCI had significantly more electromyographic (EMG) activity in the latissimus dorsi and trapezius muscles compared to able-bodied control subjects. The authors suggest that this is a compensatory mechanism to substitute for the absence of erector spinalis muscle activity. Similarly, Janssen-Potten and colleagues¹³ showed that posterior pelvic tilt was associated with more EMG activity in the thoracic postural muscles. In an intact able-bodied individual, full range of overhead reach is achieved only with spinal extension. In individuals who sit full time, there is likely to be more frequent and maintained overhead reaching. If the habitual seated posture is one of posterior pelvic tilt, spinal flexion, forward head, and rounded shoulders, and the individual has no active spinal extension, reaching will be impaired. Furthermore, reaching may even be potentially damaging to the joint structures due to increased impingement. However, this same individual may be provided with the external support of an orthotic seating system and gain significantly improved reach.¹⁴

Normal trunk innervation allows unilateral or bilateral upper extremity tasks with synergistic stabilization by the trunk muscles. In this regard, the movement strategies of the individual with truncal paralysis differ significantly from the biomechanics used in the able-bodied population. The impact of the difference in trunk stabilization is illustrated in a study that assessed

the relationship between motor lesion level and rotator cuff disorders. The authors found a significantly higher prevalence of rotator cuff disorder in the subjects with high-level paraplegia (defined as T2–T7).¹⁵ The therapeutic goal of seating is to avoid the negative sequelae of compensations for instability. Therefore, the seating system must make use of gravity to assist with attaining stability, promote optimal pelvic alignment, and allow positioning of the normal spinal curves on top of the pelvis.

The obligatory interaction between the spine and the shoulder girdle makes it imperative to recognize spinal posture as the platform for upper extremity function. Therefore, the joint angles of the upper extremity (for instance with wheelchair propulsion) cannot be ascertained without knowing the position of the trunk. In the same wheelchair with the hand at the top of the pushrim (at the 12 o'clock position), the shoulder and elbow positions and angles will differ if the buttocks are at the rear of the seat or at the front, or if the trunk leans forward. Push mechanics cannot be analyzed without considering posture. Posture impacts the range of motion of all the upper extremity joints.

When an individual uses a manual wheelchair, the propulsion of the wheelchair must be considered a potential source of stress for the shoulder. Intuitively, push mechanics appear to be important. At issue are the positions in which the joints of the upper extremity are working. Evidence supports the idea that the joint positions are a significant factor for forces across the joint.^{16–19} It is important to assess whether the wheelchair configuration is dictating movement at the extremes of joint range of motion or in positions of instability. Extremes of joint range force muscles to work at a mechanical disadvantage, usually overlengthened or overshortened, causing physiologic insufficiency. For the shoulder, hyperextension or the combination of abduction with internal rotation are positions of the joint that are not optimal for joint function; they are believed to be impinging positions for the rotator cuff muscles as they decrease the subacromial space.

Alignment, Respiration, and Skin Health

Kyphotic postures will reduce the individual's respiratory function by decreasing lung volume.^{4,20} Combined with the absent abdominal wall function, kyphosis can severely decrease the ability for forceful expulsion through coughing. In extreme cases of postural malalignment, there is difficulty with swallowing and even with management of saliva. Mechanical swallowing problems can lead to aspiration pneumonia. Decreased tidal volume can also lead to decreased phonation. Fatigue and decreased systemic ability due to decreased oxygenation are also sequelae.

Pressure sores are the most frequent secondary medical complication in individuals with SCI²¹ and are a leading

cause for rehospitalization following traumatic SCI.²² Individuals with SCI are at risk of skin compromise due to limited mobility, impaired circulation, altered sensation, abnormal muscle control, loss of tissue, and altered postural alignment. If not properly addressed, limited range of motion due to spasticity, contractures, heterotopic ossification (abnormal bone formation in the soft tissues), and spinal stabilization often lead to postural deformity that may result in increased pressures when sitting. Asymmetrical sitting postures increase the risk of skin breakdown in load-bearing areas.

Orthotic Seating

Very little information exists in the literature regarding the impact of wheelchair configuration on posture. Early work by Zacharkow²³ addressed the issue of posture and the wheelchair. He recommended a number of modifications to a standard wheelchair that would optimize spinal posture while allowing balance and function. Harms²⁴ did similar work comparing three standard wheelchair configurations used in England at the time of the study and concluded that the sling upholstery backrest created the most kyphosis and was the most uncomfortable for users. In a series of four case studies in persons with tetraplegia, Bolin and colleagues²⁵ showed that wheelchair configuration modifications did change posture and outcome measures related to pain and function. A series of lab-based studies assessing the effects of a chair configuration on balance in a bimanual reaching task concluded that a posterior pelvic tilt was a stable position,²⁶ that a forward inclination (wedging up the back of the seat) would not create an anterior pelvic tilt,¹³ and that the footrest did not appear to contribute to balance for reaching.²⁷ Tomlinson performed mathematical modeling and computer simulation to determine the impact of the manual wheelchair configuration on roll resistance, maneuverability, and stability.²⁸ However, none of these simulations brought the backrest forward to vertical, which is a key component of a pelvic-stabilizing configuration and is believed to significantly impact seated stability and balance. In personal communication, the author (Hastings) asked Tomlinson to plot the characteristics of an individual with T6 paraplegia into his simulated equation and then bring the backrest to vertical. In the model, this change resulted in an erect spinal posture with improved stability at least equivalent to the slump kyphotic sitting assumed with buttocks forward.²⁹ More recently, a therapist in Europe has developed the ergonomic seating system, which is a frame design of a wheelchair that the designer calls a "wheeled orthosis,"³⁰ and that contains the key parameters of a pelvic-stabilizing system. A study by Maurer and Sprigle³¹ assessed the seated pressure distribution of a seating configuration with various seat slopes and found that there are no significant differences in peak pressures with different seat slope inclinations. This study is significant because

it refutes one of the concerns levied by therapists against pelvic-stabilizing wheelchair configurations, that of increased ischial pressure.

Orthotic seating and the design of a pelvic-stabilizing system through wheelchair configuration are concepts that have been advanced in the literature.^{14,32,33} This approach is founded in the work of Keegan⁹ and based on the interactions of the anatomy of the pelvis and lumbar spine, the length of the muscles of the thigh, and the principles of orthotic fabrication. The pelvic stabilizing configuration uses three points of control to stabilize the pelvis in neutral alignment. The seat slope is positive (front higher than rear) and the seat-to-backrest angle is acute (generally, with the backrest being perpendicular to the floor or forward of this position). The backrest is either low or contoured to allow the normal spinal curves above a neutral pelvis. This orthotic wheelchair configuration was shown to decrease forward head posture and shoulder protraction and increase humeral elevation when compared to the standard factory setup of a lightweight wheelchair.¹⁴ Because wheelchair configuration can provide orthotic support to maintain proper spinal alignment, the wheelchair configuration can directly impact the articular function and biomechanics of the shoulder in tasks such as wheelchair propulsion, reaching, and transfers.

Prevention

Prevention science models suggest that the crux of prevention is to identify and reduce known risk factors while enhancing protective factors.³⁴ Postural malalignment is a known risk factor for musculoskeletal pain, and optimal spinal alignment is a protective factor. The support of optimal spinal posture is the key to prevention of potential musculoskeletal pain, as well as a treatment for existing pain secondary to malalignment and muscle imbalance. In a study assessing the spinal deformities in adults who were acutely spinal cord-injured prior to the age of 16 years, Bergstrom³⁵ found a high prevalence of scoliosis and kyphosis. The author suggested that habitual positioning in poor alignment was a contributing cause and that maintenance of seated posture that most closely mirrors the alignment of the spine in a standing position may prevent or reduce spinal deformity.

Identification of modifiable factors is essential to the development of an optimal treatment program. In the presence of trunk paralysis, the immediate environment of the wheelchair and the extent to which it provides postural support is a modifiable factor and the target of a seating intervention. The intervention is *postural change*; the mechanism of obtaining this intervention in a population with truncal paralysis secondary to SCI is the configuration of a customized seating system.

Theoretically, upper-quadrant musculoskeletal pain after SCI has two main and interrelated causes: postural pain and pain from aberrant upper limb joint biomechanics.

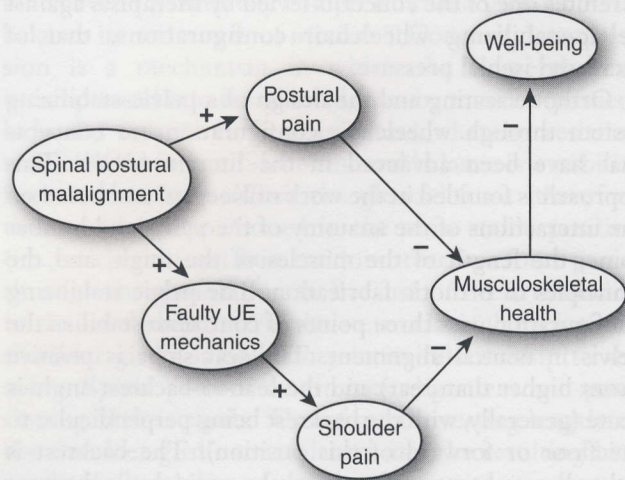


Figure 8-1. Poor postural alignment has negative sequelae. Failure to achieve proper spinal postural alignment with optimal wheelchair seating results in poor push mechanics and pain. These factors in turn degrade musculoskeletal health and ultimately have a negative impact on quality of life and overall well-being.

The posture of the individual is a direct predictor of pain and also indirectly contributes to pain through upper extremity biomechanics (Fig. 8-1). Further spinal postural malalignment can negatively impact health even in the absence of pain. Postural malalignment contributes to skin breakdown, impaired respiratory function, and poor self-image. Physical health impairments, to the extent that they interfere with social engagement and social participation, are known to be linked to decreased quality of life.³⁶

The Mobility Base

Functions of a Wheelchair

A well-prescribed wheelchair is a mobile seating orthosis and, as such, can stabilize, support, enhance, or substitute for function. As with any orthosis, the design and configuration of the wheeled orthosis is dependent upon the impairments and functional needs of the individual. Likewise, to determine the specifications of the orthosis, a careful physical examination (including testing of motor and sensory integrity and passive range of motion) is performed in complement with a movement evaluation and an assessment of the environmental needs.

Much of the remainder of this chapter will discuss the components of the evaluation that lead to the determination of the postural support needs that must be provided by the system. The functional assessment addresses the question, "What does the wheelchair need to do for the individual with SCI?" On the face of it, that may seem to be a foolish question. Obviously, the wheelchair allows mobility in the place of walking. For the most able individual with SCI having mastery of diverse wheelchair

skills and functional mobility, that is indeed the sole function of the wheelchair. However, there are many variations in the functions of wheelchairs. A poorly prescribed wheelchair can actually *limit* function. This section of the chapter will illustrate how the optimal functional tasks of the wheelchair for a given individual can be predicted based on an assessment of the environment, the lifestyle, and the individual's current (and potential) functional skills.

There are three basic roles the mobility base can provide. These are mobility, a seated position, and a platform for function. There is a wide range of function within each of these categories, and it is necessary to define the specific needs of the individual. There are factors to be considered regarding mobility. Is this the all-day and exclusive form of mobility? Does the individual have any walking ability, even for short distances? If the individual stands or partially stands for any functional activity, the front frame length and the footrest configuration is a consideration. Does the individual drive? If not, then the wheelchair provides much more mobility. What kinds of distances or terrain are likely to be traveled? For what duration of time is the individual away from home? If the individual does not drive, access to public transportation and maneuverability within its confines must be considered, as well as weight limits for lift equipment (i.e., for power wheelchairs). Additionally, portability of the wheelchair for transportation in the vehicles of friends or caregivers must be considered. How easy is the wheelchair to transport? In the case of a power wheelchair that will provide the primary source of community mobility, consideration of ground clearance, battery life, and durability is important. If the individual does drive, what kind of vehicle will be used? If it is a lift- or ramp-equipped vehicle, then weight limits, head clearance, and maneuverability in the vehicle, and wheelchair handling skills, must all be considered. If the individual will stow the wheelchair into the vehicle, the therapist must consider where and how it will be stowed. The vehicle may dictate some features of the wheelchair. For the individual who is newly spinal cord-injured and who is purchasing new equipment, vehicle suggestions can be made to allow optimal wheelchair selection. However, a vehicle is a larger investment than a wheelchair, and existing vehicles may dictate wheelchair parameters.

Body Weight

The body weight of the wheelchair user is a factor that must be considered in wheelchair prescription. Individuals over 250 pounds are over the weight limit for many manufacturers' light and ultralight wheelchairs, requiring wheelchairs to be reinforced to accommodate the body weight. Many companies will not warranty folding wheelchairs at the higher rider weight, yet rigid wheelchairs can be a problem for these individuals. The larger user and the larger wheelchair strain the clearance

behind a steering wheel when attempting to stow the wheelchair in a car. Some manufacturers are producing newer-technology folding ultralight wheelchairs that handle higher body weight; this may be a better option for driving independence. Body weight is also a factor for the power wheelchair user as the combined weight of the user and the wheelchair cannot exceed the load capacity of lift equipment for transportation.

Self Care

If the individual dresses in his or her wheelchair, this places certain requirements on the configuration of the wheelchair. Some flexibility may be required in the backrest to allow for the trunk extension to lift the hips for pants clearance. Also, for this technique, there will be an increased need for rearward stability of the wheelchair. Alternatively, if the technique is to scoot forward and lift hips with flexion and hip hiking, then a slightly longer front frame may be beneficial. In power equipment, the ability to open the seat-to-backrest angle may facilitate caregiver ability to manage clothing.

Individuals who use wheelchairs full time will be required to perform bladder management from their wheelchair; therefore, consideration must be given to how the individual voids. Leg bag management requires the ability to maneuver the wheelchair closer to a toilet for spill-free drainage. The individual who self-catheterizes may need more seat depth or front frame length to maneuver into a posterior pelvic-tilted position within the wheelchair, while a seat depth that is too long will interfere with voiding into a urinal. Those requiring caregiver support may have specific equipment needs to allow efficient and safe assistance.

Seated Position

Assessment of lifestyle and abilities are key factors in determining the functions of the wheelchair in this category. At one extreme, for the individual with high tetraplegia who is dependent for all mobility needs, the wheelchair provides the all-day seated environment. The wheelchair functions must therefore include the ability to change positions for pressure relief and to support the performance of functional activities to the client's fullest capabilities. Power seat functions such as tilt, recline, and elevators, or a combination of all three, may be required to meet the individual's needs. At the other extreme, if the individual has mastery of a wide variety of transfers, alternative positional functions in the wheelchair are typically not required. This individual will transfer out of the wheelchair to drive, to relax, to watch a movie, to exercise, etc. For this individual, the wheelchair can be setup for a single-seated position that optimizes posture and wheelchair propulsion ability.

Somewhere between the extremes illustrated by these two cases is the individual with marginal transfer skills, or

who requires assistance, who may not get out of the wheelchair with any frequency during the day. If this individual drives a vehicle from the wheelchair, they will require a higher backrest on the wheelchair, and a headrest is recommended. They may also desire armrests or other accessories to optimize seated stability.

Wheelchair Skills

Wheelchair skills, and especially wheelie mastery, heavily influence the functions the wheelchair must provide. If an individual has minimal wheelchair skills and/or poor ability in wheelchair propulsion, then the wheelchair must provide for the biomechanics of an assistant. Push handles and higher backrests may be needed. Larger caster diameter will traverse terrain obstacles easier and may be needed if the individual cannot lift casters to clear these obstacles.

Transfers

The individual's method of transferring to and from the wheelchair must be considered to encourage optimal techniques and efficiency. For the individual who transfers independently with either one or both feet on the floor, front frame design is important in order to allow appropriate foot placement. Swing-away leg rests or flip-up footplates are preferred by some to allow a firm contact of both feet on the ground while minimizing the influence of the front frame. When the individual maintains the feet on the footrest during an independent transfer, the orientation of the front frame relative to the caster placement should provide forward and lateral stability of the wheelchair. Individuals who require a positive seat angle (front seat height greater than rear seat height) often require specific transfer training to support independence. For those who transfer with assistance or by dependent methods, swing-away and removable leg rests are beneficial. When the individual performs assisted transfers with feet on the ground, seat-to-floor heights must be considered.

Foot Propulsion

If the individual propels the wheelchair with the feet, then the configuration will be distinctly different from an arm-propelled wheelchair. There are obvious needs for lower seat-to-floor height and having either removable footrests or omitting them altogether; however, it is also necessary to think about upper extremity support and increasing the anterior space for improved foot maneuverability. The functional demands on the wheelchair are more limited in terms of the usual terrain it will cover, but they are also more varied as it is likely that it will be necessary to set up the wheelchair for the independent foot-propelled function as well as the dependent propulsion over long distances or rough terrain.

Social Roles

Individuals who work or travel have equipment preferences to allow them to be optimally functional in varied environments. Wheelchair users with young children may also express specific needs for their seating system. A thorough assessment of the individual's social roles,

lifestyle, environment, functional abilities, and limitations will help the therapist derive a list of wheelchair requirements to meet the function-specific demands. Now, the therapist is ready to guide the selection of specific wheelchair components. Table 8-1 provides information on the basic manual wheelchair components.

Table 8-1
Basic Manual Wheel Chair Components

Component	Usual Options	Considerations
Casters	Diameter ranging from 3 to 8 inches. <i>Material options:</i> Polyurethane Pneumatic Semi-pneumatic/soft roll	Larger diameter traverses obstacles more easily. Smaller diameter casters have less roll resistance and turn with greater ease. Foot clearance: Larger diameter casters usually require more forward foot position for clearance. Wider contact will increase roll resistance, especially for turning. Narrower contact decreases roll resistance and increases vibration from terrain obstacles. Pneumatic casters lose air quickly (increase maintenance) and low pressures will increase roll resistance.
Rear wheel	Diameter <i>Wheel Options:</i> Spoked with high or low flange "Mag" High-end composites <i>Tire options:</i> Pneumatic: Range of pressures from high to low (110 lbs/inch ² to 45 lbs/inch ²) Airless inserts <i>Tread options:</i> Range from smooth to mountain bike tire Composite tires	Rear wheel diameter (22 to 26 inch) should be considered along with axle position to ensure good arc of push without excessive joint motions. In general, larger diameter wheels offer less resistance. Larger wheel size traverses terrain more easily. Aluminum spokes are lightweight and provide some shock absorption, but require maintenance. "Mag" wheels are heavy, but require no maintenance. Composites purport a smoother ride and are lighter than aluminum spokes. Air is a shock absorber, therefore more air at lower pressure provides more shock absorption. Higher pressure provides less roll resistance. Airless inserts add a significant amount of weight. Tread selected is determined by the environment of use. Higher tread provides more traction and increased roll resistance. Generally, these tires have smooth to low tread features and offer an alternative to airless inserts. They are heavier than pneumatic tires, with less shock absorption.
Armrests	T-shaped single post	The amount and frequency of weight bearing on the armrest should be considered. T-shaped armrests are better for weight bearing, although no armrests are designed to support full body weight.

Table 8-1
Basic Manual Wheel Chair Components—cont'd

Component	Usual Options	Considerations
	L-shaped swing away	Swing-away armrests generally have a separate side guard and allow the rear wheel to be positioned closer to the frame.
	Flip back	Flip-back armrests are less stable laterally.
Push handles	Bolted on to rigidizer bar (rigid frame wheelchair)	Consider ease of reach if the rider uses hooking for functional stability.
	Integrated in back cane	If the backrest is low, with acute seat-to-backrest angle to provide lumbar support, then the integral push handles may interfere with push or cause rubbing on the lateral trunk.
	Some manufacturers offer fold-down integrated push handles, quick-release, or height-adjustable push handles.	If push handles are for occasional assistance, then consider removable and higher placement for improved mechanics.

Manual Wheelchairs

The ideal manual wheelchair is lightweight, durable for long-term use, and custom-configured to meet the specific needs of the intended user. While many manual wheelchair options exist, the ultralight class of wheelchairs is the best choice for the consumer with SCI due to its inherent features. The ultralight offers a number of adjustable features and configurations for individualized customization and is the lightest-weight option available. The ultralights are the easiest to manage. Because decreased weight is directly related to decreased roll resistance, a lighter-weight chair requires less force to propel. Lower force propulsion is important for minimizing the risk of upper extremity pathology in wheelchair users as high forces are correlated with shoulder pathology,^{37,38} pain, and injury at the wrist.³⁹ Additionally, an ultralight is the easiest to manage when the wheelchair user is not in the wheelchair, as in the case of stowing the chair in a vehicle. In addition to the lightweight nature of the wheelchair frame, ultralights typically have a rear wheel quick-release feature that disengages the rear wheels when the axle pin is manually depressed. This allows the wheels and frame to be lifted independently, which requires less upper extremity work than managing the entire assembled system. When compared to the other classes of manual wheelchairs, the ultralights are the most durable, as higher-quality materials are used for the frames, components, and accessories. Superior durability means that ultralights are more cost effective despite a higher initial purchase price, and they may also be a more reliable and safer selection.⁴⁰

The ultralights are the only class of manual wheelchairs that allow customized configuration. In addition to selection of seat sizes, frame designs, and accessories,

ultralights can be configured and adjusted to optimize performance and functional independence while minimizing injury risk. Whether by adjustment or custom build, the ultralight can be specifically fit to the consumer in a manner that allows for comfort,⁴¹ postural support,¹⁴ skin protection,⁴² and efficient wheelchair propulsion.^{43,44} One key feature unique to the ultralights is adjustability of the rear wheel in multiple planes. The rear wheel is adjustable forward in the horizontal plane, which has been demonstrated to improve push mechanics^{17,43,45,46} and therefore potentially reduce the risk of upper extremity injuries. The rear wheel should be positioned as far forward as possible without causing the wheelchair to be unstable rearward ("tippy").⁶ Orientation of the rear wheel in the vertical dimension can be fixed or adjusted in the ultralight chairs. Once posture is optimized, the rear wheel should be positioned such that the distance between the shoulder and wheel hub is minimized⁴⁷ and the elbow angle (with the hand at top dead center of the handrim) is between 100 and 120 degrees.^{17,48}

Products vary widely within the class of ultralight wheelchairs. Generally, frames are available in either folding or rigid form, with a wide range of configuration and component options available. Selection of the appropriate ultralight is based on findings from the comprehensive evaluation, therapist knowledge of available options, and client preferences.

Folding ultralight wheelchairs range in design from highly adjustable to completely custom. Most clients who prefer folding chairs are long-term wheelchair users whose habitual technique for stowing their wheelchair into their vehicles is to fold it, usually without removal of the rear wheels. The collapse of the folding wheelchair for stowage in a vehicle is a primary benefit of this frame

style. One concern with most folding wheelchairs is that postural support is compromised when the back angle is at a fixed position of a 90-degree backrest-to-seat angle. In effect, this will result in the backrest being reclined when there is a positive slope (front seat height higher than rear seat height). To preserve optimal postural alignment, a folding chair with either an adjustable or custom-specified back angle is recommended. A second concern with folding ultralights is lost push efficiency due to the inherent flex in the frame. Folding ultralights with either a locking center frame or articulated rigid footplate may reduce folding frame inefficiencies.

Nonfolding, rigid ultralights can be specifically adjusted or custom ordered to optimize postural support. They are efficient to push because upper extremity forces applied to the wheel are not diminished by flex in the frame. The rigid wheelchairs vary not only in degree of adjustability but also in the style or design of the frame. In general, adjustments for seat-to-backrest angle, backrest height, and footrest length are available, while degree of adjustability of other features depends on the style of the frame.

One style of rigid ultralights is the box frame. The rigid box frame wheelchairs have a top frame tube and a bottom frame tube with at least one cross tube welded to both sides (Fig. 8-2). With the most adjustable box-style welded frame, the rear wheels and front casters are mounted to the frame tubing by plate interfaces. On these frames, most of the components and accessories can be moved on the frame in multiple dimensions to customize the fit to the user. As an example, the rear wheel can be moved horizontally, vertically, and laterally without additional parts. Another option in the box-style

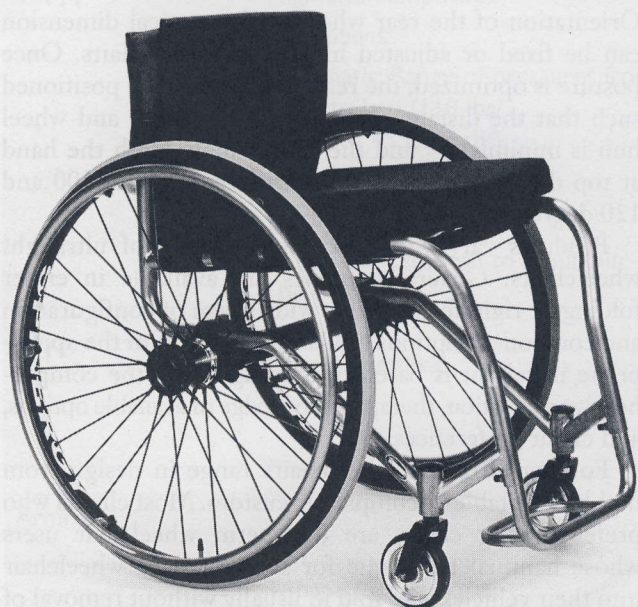


Figure 8-2. Box-style frame rigid manual wheelchair. (Photo courtesy of Invacare Top End.)

wheelchair is the welded frame with an axle tube spanning the width of the chair to interface with the rear wheels. The frame is built to specified dimensions. Typically, only adjustment of the rear wheel in the horizontal plane is available. The minimization of moving parts and adjustments typically provides improved comfort, efficiency, and performance.

Another option in rigid ultralight manual wheelchairs is the squeeze frame. This frame design has a hinge at the front of the frame to allow rear seat height adjustment by moving the rear seat position up or down. The rear wheel position is fixed in the vertical dimension. Since the rear wheel does not move up or down, the front caster housing is fixed. Rear wheel adjustment in the horizontal plane is preserved.

A popular low-profile frame is the cantilever or mono-tube design, also referred to as a *minimalist* frame (Fig. 8-3). With one style of cantilever wheelchair, the rear wheels are mounted by brackets suspended from, and extending below, the rear frame. When the rear wheels are removed, the cantilever style typically has the lowest profile frame of all the chairs, making it easier to maneuver the wheelchair when stowing into a vehicle. With the adjustable cantilever models, there are many options available for seat angle configuration and rear wheel position. However, along with adjustability comes more moving parts. In some cases, this adds increased weight despite the appearance of low weight with a minimal frame design. Additionally, it is important to remember that the more adjustable parts there are on a wheelchair, the more potential for breakage or maladjustment.



Figure 8-3. Cantilever-style frame rigid manual wheelchair. (Photo courtesy of TiLite, Kennewick, WA.)

On frames where there are both adjustable components and fixed components, it is important to recognize the secondary impact of purposeful adjustment. For instance, with the front hinge-style frame, the result of increasing the seat slope (lowering the rear seat height) is that the user sits deeper in the wheels (i.e., closer to the axles), thereby increasing the joint excursion of all upper extremity joints during propulsion. Additionally, this change causes the knee position to be more flexed. In contrast, with a cantilever frame design, increasing the seat slope will not change the knee angle, but will position the footrest at a more forward angle relative to the floor and increase the overall length of the wheelchair. For all chairs that allow adjustment as an inherent feature, it is important to confirm that desired chair alignment is preserved when extremes of adjustments are used. For example, when the rear seat height is adjusted to the lowest setting, the backrest should still achieve a vertical position and the front caster housing perpendicular orientation must be maintained.

The most advanced style of ultralight manual wheelchairs is the custom-configured welded frames. Available in a number of different designs from several manufacturers, the welded chairs are manufactured based on specific prescribed dimensions for all aspects of the chair. In addition to seat width and depth, the chair is built to specific dimensions relative to front and rear seat heights, frame lengths, backrest orientation, caster position, and footrest design. Depending on the manufacturer and the specific model, adjustability in rear wheel horizontal position and backrest angle can be preserved to fine-tune the fit of an otherwise fixed frame. Generally, some adjustment of backrest height and footrest length is maintained to accommodate different cushion heights. Because the welded chairs are custom designed for the specific consumer and are constructed with few moving parts, they are the lightest-weight, most durable, most highly maneuverable, and most energy-efficient chairs available. However, because there is minimal adjustability, the skills of a highly experienced and confident therapist are required to design and fit a fixed wheelchair that best meets the complex needs of the user with SCI.

Many ultralights are also available with suspension. The function of suspension is to absorb shock that is transmitted through the wheelchair. Suspension frames are available in both adjustable and highly customized models. The location of the suspension on the frame and the type of system used varies by manufacturer. Several chairs have the suspension located directly under the seat, with attachment to both the frame and underside of the seat. When the system is "loaded" by the individual sitting in the chair, the hydraulic system under the seat will compress. In a center-mount suspension design, the seat sinks between the two wheels when the suspension device is loaded. By contrast, other suspension chairs use independent rear wheel suspension. Either a spring or elastic polymer is incorporated into the mounting

hardware for each rear wheel. When the seat is loaded, the suspension device at each wheel compresses independently. The independent rear wheels will respond to an asymmetric load, as occurs when traversing uneven terrain. With either suspension design, the rear seat height will be lowered when the suspension device is loaded; therefore, it is critical to evaluate the implications for seat slope, backrest position, and rider orientation to the rear wheels for propulsion. Suspension for front casters is also available as an accessory that can interface with most manual wheelchairs. Potential clinical indications for rear and/or front suspension include improved ease and comfort when negotiating uneven terrain and decreased jarring and vibration during wheeling. Cooper and Wolf⁴⁹ evaluated shock and vibration at the seat and footrest in wheelchairs with and without suspension. They found that shock and vibration is reduced with caster fork suspension more than with rear frame suspension. While there are identified benefits to the use of suspension with manual wheelchairs, the choice must be balanced with consideration of increased weight to the system, maintenance needs, and potential impaired efficiency of propulsion on varied surfaces.

Regardless of the style of chair selected for an individual, the dimensions and configuration of the wheelchair deserve critical attention in order to maximize mobility, support, and comfort. Additionally, the prescribing therapist must clearly understand the reference points for all chair dimensions, which will ultimately dictate the configuration of the final wheelchair. Unfortunately, reference dimensions vary from one manufacturer to another, so for each manufacturer there is only one correct way to measure. The therapist is urged to *read the directions* on the order form with care.

Manual Wheelchair Propulsion Assistance

Add-on rear wheel options that provide assistance during propulsion are available for certain models of wheelchairs. These rear wheel propulsion-assist technologies are typically accessory devices that are mounted and interfaced with a new or existing manual wheelchair and are targeted toward improved mobility as well as decreased pain and risk of upper extremity injury for individuals who propel manual wheelchairs.

One available option is the pushrim-activated power-assist wheelchair (PAPAW). The wheelchair is accessorized with battery-powered wheels that provide supplemental power output when the handrim is engaged during propulsion. Depending on the manufacturer, the power wheels may interface with just one type of wheelchair or may be retrofitted to a wide range of wheelchairs by alternative mounting hardware. Arva and colleagues⁵⁰ found that metabolic energy and user power were lower, and mechanical efficiency higher, during propulsion with the PAPAW. Laboratory findings associated with the PAPAW include decreased

energy demands,⁵¹⁻⁵⁴ decreased stroke frequency,⁵² decreased upper extremity range of motion during propulsion,⁵⁵ and decreased surface EMG of upper extremity muscles.⁵⁶ Alsgood and colleagues⁵⁴ found that individuals with tetraplegia traversing a four-obstacle course in both standard manual wheelchairs and with PAPA W. Functional wheelchair skills do not appear to be significantly influenced by the use of PAPA W. In a study comparing acquisition of wheelchair skills in a wheelchair with standard rear wheels versus power-assist wheels, there was no significant difference in skill achievement as measured by the total score on a wheelchair skills test.⁵⁷ However, the authors noted that the added torque appeared to offer an advantage for skills for which power was required (such as inclines), but disadvantaged skills requiring control (such as wheelie-based skills). This study was done in able-bodied subjects, so the results may not be generalized to clients with SCI who have limited hand function. Evidence supports the metabolic benefit and the increased torque provided by PAPA W; however, it is not clear whether there is an overall improvement at the community participation level. A community-based study⁵⁸ found no difference in distance traveled in a 2-week period in manual wheelchairs versus PAPA W.

Another rear wheel accessory specifically designed to aid wheelchair propulsion is a geared wheel that allows the individual to switch between standard pushing and a lower gear. Similar to riding a geared bicycle, the low gear provides decreased resistance to propulsion. With decreased resistance over a given terrain, the wheel is easier to propel, but it requires increased push frequency to traverse the same distance. Preliminary reports suggest that the geared wheel may decrease upper limb pain⁵⁹ but more research investigation of the geared rear wheel is needed.

Accessory rear wheel options appear to offer some benefit to individuals who prefer to continue pushing a manual wheelchair versus transitioning to a power wheelchair. When considering prescription of add-on wheels, the ability of the users to operate the wheels must be evaluated, in such areas as turning the assistance on and off, installing and removing the wheels, and ease of charging the battery. These considerations are especially important for the individual with tetraplegia with upper extremity weakness and impaired hand function. Evaluation of management of the wheelchair with power wheels must also take into consideration tasks such as stowing the wheelchair in a vehicle. The significant weight of each wheel creates an increased risk for injury when attempting independent stowing of the wheels. It is recommended that an individual using add-on wheels use a van with a lift or ramp or, if traveling in a car, seek assistance for stowing the wheels. Battery life and how it is affected by the terrain the individual typically traverses are important factors to consider when assessing for

power-assist wheels. For the currently available power-assist systems, there is significant added weight and roll resistance if propelling the wheelchair without the power-assist feature engaged. Other considerations for the rear wheel propulsion-assist accessories include maintenance needs, cost, and the need for additional wheelchair skills training.

Power Wheelchairs

Power wheelchairs are the appropriate equipment choice for many individuals with SCI. Like manual wheelchairs, there are a multitude of power wheelchair options with variable features and functions. The ideal power system is one that best meets the comprehensive needs of the client, with decisions guided by a thorough assessment combined with simulation and trials of appropriate options. The power system must provide maximal mobility while also meeting the fundamental seating goals for postural support, comfort, skin protection, and optimized function. Because the needs of individuals with SCI who require power mobility are typically complex, most are best served by a power base with an adjustable "rehab-style" seat that is designed to meet the dimensional, postural, comfort, and functional needs of a person and can also accommodate dynamic power seat functions such as tilt in space, reclining backrests, and seat elevation. Scooters and basic power wheelchairs with integral seats (i.e., captain's seating) usually do not adequately address mobility and seating requirements for the client with SCI. For aggressive, full-time wheelchair users functioning in both indoor and varied outdoor environments, wheelchairs must be highly maneuverable, durable, and reliable, both in known and unpredictable circumstances. Fass and colleagues⁶⁰ found the most advanced, high-end, custom wheelchair bases to be the most durable. Individuals with higher-level cervical injuries require a power system that will meet mobility and support needs and also interface with alternative specialty controls to allow them to operate their power system and to control their environment. The following overview of power bases, power seat options, and input devices will guide clinical reasoning for power system recommendations for the client with SCI.

Power wheelchair bases are available with a variety of features, including control processor capabilities (i.e., programmability of control parameters including speed, acceleration, braking, and tremor dampening), suspensions, and motor packages. A common method of comparing bases involves position of the drive wheels, such as rear wheel drive (RWD), front wheel drive (FWD), and midwheel drive (MWD). Within these three general categories, there are significant variations of the drive wheel position with different manufacturers and models. The drive wheel position relative to the power base and relative to the seat orientation over the base carries significant implications for wheelchair performance.

Factors influenced by drive wheel position include turning radius, overall wheelchair length, maneuverability, speed, stability, traction, and the ability to negotiate obstacles. There are inherent benefits and concerns for each of the power base options. The appropriate power base selection for the individual requires that the pros and cons of product options be carefully weighed and integrated with the client's specific needs and preferences. Fass and colleagues⁶⁰ identified no differences in durability between RWD, FWD, and MWD power wheelchairs. There is currently no published research to support that one drive wheel position is superior to another.

A RWD power base has the large drive wheels positioned posteriorly, relative to the center of the base, with smaller casters at the anterior aspect of the base. The seat is positioned such that the driver's center of gravity (COG) is forward of the drive wheels. With this posterior placement of the drive wheels, power to the wheels functions to "push" the wheelchair forward when it is activated by the driver. A low-ratio RWD configuration allows for a smaller percentage of driver body weight (~65%) over the drive wheels, while a high-ratio RWD allows for a greater percentage of driver body weight over the drive wheels (~85%); these are factors that impact drive performance.⁶¹ Traction is improved with increased weight over the drive wheels. Relative to other power bases, RWD performance is most consistent with increased stability at high speeds and predictable reaction on uneven surfaces. The RWD power wheelchairs typically have a longer wheelbase, with an associated increase in turning radius. RWD wheelchairs are most stable while descending inclines, but may be unstable on steep ascents (rearward instability). Additionally, the rear-positioned drive wheels are challenged for uphill climbing because of increased power demands. When traversing a side slope, the inherent configuration of RWD will cause the front of the wheelchair to turn downward, the extent of which is highly dependent on the weight over the casters. The RWD wheelchairs are less maneuverable over thresholds, obstacles, and in soft terrain because the front casters must first overcome the environmental challenge. A key consideration relative to the front casters is lower leg and foot position. To allow clearance for caster swivel without contacting the driver's foot, the front rigging (i.e., leg rest and foot support) typically needs to extend forward from the seat, which may result in an increased overall wheelchair length.

The FWD power base is configured with the large drive wheels most forward on the base and the smaller casters trailing behind (Fig. 8-4). The driver's COG while seated is behind the drive wheels. Because the seat is positioned over the base, the footrest is the most forward aspect of a FWD power wheelchair and therefore must be considered relative to obstacle negotiation. Having the footrest positioned forward of the anterior drive wheels allows for many options in lower leg and foot position. Similar to RWD, there are low-ratio and

high-ratio wheel configurations in FWD systems.⁶¹ With the drive wheels located anteriorly, input to the wheels functions to "pull" the wheelchair in the desired direction. FWD wheelchairs have a wheelbase similar to that of RWD wheelchairs; however, the maneuvering configuration is quite different. Driving a FWD wheelchair has been described as similar to driving a forklift, because the major part of the wheelchair is posterior to the drive wheels. FWD wheelchairs are known to be less stable at higher speeds and are more difficult to control over uneven terrain. However, recent improvements in technology have improved tracking and overcome instability concerns with most FWD wheelchairs, which are especially beneficial to those driving with switch-activated controls. FWD wheelchairs likely represent the most effective wheelchair for negotiating thresholds and obstacles and also for ascending small curbs. This is because the large drive wheels encounter the challenge first and function to pull the wheelchair up and over obstacles. FWD wheelchairs are highly effective for climbing hills, but are less stable than other bases for descending inclines. On a side slope, the rear aspect of a FWD wheelchair turns downward, forcing the front of the wheelchair to turn upward and requiring the user to compensate with driving skill.

The MWD power wheelchair bases have the large drive wheel positioned centrally on the base under the driver's center of mass. Depending on the specific model



Figure 8-4. FWD power wheelchair. (Permobil C500, courtesy of Permobil, Inc.)

and configuration, the drive wheel may be biased forward or rearward, which impacts wheelchair performance in varied conditions. The MWD wheelchairs typically have the shortest wheel base and smallest turning radius, which may make them easiest to manage for sharp turns and tight spaces. MWD wheelchairs have the most weight over the drive wheels, which improves traction, but compromises forward and rearward stability. To compensate for instability, front and rear casters or "stabilizers" are necessary, such that MWD wheelchairs function with six wheels. With static stabilizers (those that do not change position), the wheelchair may high-center or get stuck over grade transitions, such as when driving from a flat surface to a ramp. Dynamic stabilizers, or independent suspensions on the front and rear stabilizer wheels, prevent high-centering and allow for improved obstacle negotiation and control in unpredictable terrains. Technological developments for MWD wheelchairs are targeted toward increased stability in all environments. The impact of increased speed on stability depends on the bias of the center wheel backward or forward, which correlates with identified tendencies of the RWD and FWD wheelchairs, respectively. MWD wheelchairs tend to be the least predictable for straight line driving on a side slope, because the pull of the wheelchair upward or downward is influenced both by the actual position of the drive wheel and by the specific side slope. MWD wheelchairs have more footrest options than RWD, but the orientation of the lower legs and feet must be considered relative to the front stabilizers.

A power seat with dynamic functions mounted to the selected power base provides necessary body movement that is typically compromised as a result of SCI. While the power base allows the individual to move from one place to another and to maneuver in varied environments, the power seat provides for specific changes in body position, which promotes physiologic health, comfort, postural support, and energy conservation. Power seat options include recline, tilt (two dimensions), seat elevation, standing, and leg rest elevation (Fig. 8-5).

The selection and configuration of power seat options are based on assessment of client needs balanced with consideration of the specific benefits and concerns associated with a given feature. Interaction between components must also be considered. While power seats offer a number of inherent advantages, installation of a power seat can result in increased seat-to-floor height and increased overall wheelchair length as compared to standard nonpowered seats. Actuators, which mechanically control the power seat functions, must be stacked to allow for multiple seat functions (i.e., tilt combined with elevation), which will increase seat-to-floor height.

Power recline pivots the backrest posteriorly, increasing the seat-to-backrest angle and allowing the user to assume a more recumbent position. Power recline is used as a pressure-relief technique; improved pressure distribution is provided and high pressures are shifted away from the

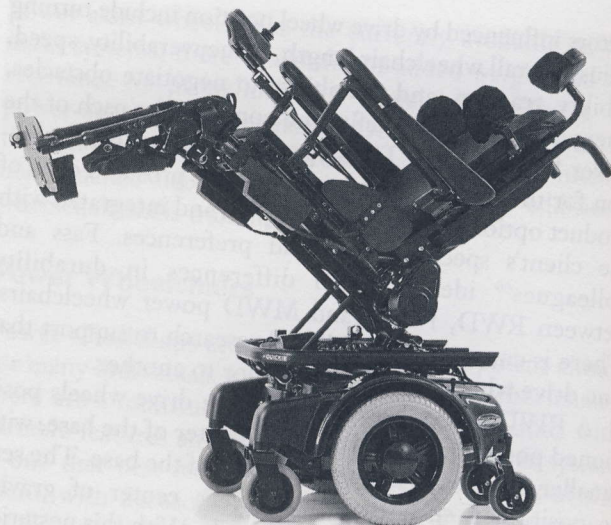


Figure 8-5. Tilt power seat function.

sitting surface when a much greater surface area is available. Published research relative to the extent of recline necessary to achieve adequate pressure relief is limited. Two studies have indicated that there is a significant decrease in seated pressures with recline but also found increased shear forces.^{62,63} In a study of 63 healthy subjects, Stinson and colleagues found that average pressures were reduced with recline at 120 degrees; however, maximum pressures were not significantly altered.⁶⁴ There is no published research evaluating the seated pressure associated with varying degrees of recline greater than 120 degrees, independent of other seat functions. Recline may be indicated when the seated individual cannot achieve upright sitting, such as when available hip flexion range of motion is less than 90 degrees or in the case of a fixed thoracic kyphosis wherein recline restores vertical head position. Recline can be used to allow a position of rest, away from upright sitting. Power recline allows for an increased hip angle, which may be beneficial for dynamic passive joint motion, comfort, improved access for bladder management, and increased ease of clothing adjustment. There are several concerns relative to recline systems used by the Client with SCI. As the backrest moves through recline and the return to neutral, shear forces at the buttocks and posterior trunk increase the risk of skin breakdown. Recline creates a challenge for maintaining postural support. As the backrest comes forward to return to an upright position, the user may be pushed forward in the seat, compromising postural alignment and support. Most people who require a power-reclining backrest lack the functional mobility to correct their seated position. Highly contoured cushions and backrests are not typically compatible with recline systems due to the potential shift in body alignment. Additionally, for those with upper motor neuron injuries, such as SCI, movement into a supine position may elicit a spastic reflex that may further compromise position in the wheelchair.

Power tilt allows the entire seat to pivot while maintaining the seat-to-backrest angle. While rearward tilt is most commonly prescribed, power tilt is also available in the forward and lateral directions. Rearward tilt is another mechanism used for pressure relief as weight is shifted from the seated surface to the posterior trunk in the tilted position. Henderson and colleagues⁶⁵ demonstrated that there is a significant decrease in seated pressures with 65 degrees of tilt, but only minimal change in pressure with 35 degrees of tilt. The distribution of pressure while tilted is likely not as good as that achieved with a fully reclined position as less surface area is available, although this has not been reported in the scientific literature. However, because the pressure relief provided by tilt lacks the shear effects inherent with full recline, tilt is the preferred method for preserving skin integrity. Like recline, the tilted position is beneficial for shifting body orientation in space and as a position of relative rest. The benefits to tilt are that body position is maintained through the excursion into tilt and back to upright, thereby eliminating shear and allowing the individual to maintain postural alignment and support. Tilt systems do not allow for passive joint motion as there is no change in seat angles; therefore, access for bladder management may be a challenge for some users. Because the flexed body posture is consistently maintained, extensor spasticity is better controlled in a tilt system. While not commonly prescribed for the SCI population, forward tilt may have a specific benefit related to transfers for the client with partial lower limb innervation whose feet are supported on the ground for assisted or independent transfers. Lateral tilt may be effective for providing vertical upper body and head alignment for the individual who sits with severe pelvic obliquity and excessive trunk curvature.

A combination power tilt and recline seat may be an appropriate choice for the client with SCI who will benefit from the advantages of each system. In a tilt/recline combination system, the driver first tilts the wheelchair, then reclines the backrest. The reverse maneuver (return from recline, then return from tilt) is used to achieve the upright seated posture. The major negative aspects of recline—shear forces on the skin and a shift in body position—are negated when the seat is in the tilted position, as the impact of gravity on the body is minimized. The concern for fixed hip position with tilt is addressed as recline following tilt allows partial extension of the hip joint without facilitating extension reflexes. The goal of the combination of power tilt and power recline is to reduce pressure and minimize shear. Hobson⁶² demonstrated that maximum pressure and shear reduction was achieved with 120 degrees of recline and 25 degrees of tilt. Pellow,⁶⁶ in a case series on two subjects with C5 tetraplegia, found the greatest pressure relief with a combination of 150 degrees of recline and 45 degrees of tilt. Vaisbuch and colleagues⁶³ studied five seated positions for 15 children with complete paraplegia due to

myelomeningocele and 15 nondisabled children. While tilt alone and recline alone were found to significantly decrease seated pressures, the combination of tilt with recline reduced pressures to the greatest degree. Aissaoui and colleagues⁶⁷ evaluated multiple combinations of tilt and recline in 10 able-bodied subjects in a simulation chair. The greatest pressure relief was demonstrated with 45 degrees of tilt and 120 degrees of recline. Compliance with use of powered tilt and recline systems was evaluated in a study reporting the results of 40 client interviews.⁶⁸ Ninety seven and a half percent of subjects used their power tilt/recline systems daily, predominantly to provide comfort and a rest position. Further research is necessary to specify clinical indications and optimum tilt and recline angles for individuals with SCI.

Power seat elevation allows the entire seat to translate upward in space while all seat angles and system configurations are preserved. Seat elevation allows improved environmental access in home, work, and community environments by providing a vertical upward transition that allows the individual to interact above the standard seated level.⁶⁹ Personal interactions at eye level may provide improved psychosocial adjustment for wheelchair users. Eye level communication reduces the need for chronic cervical hyperextension and may thereby decrease musculoskeletal pain in persons with limited ability to adjust position. Kirby⁷⁰ reported that sustained cervical extension and rotation resulted in increased neck discomfort in wheelchair users. Power seat elevation facilitates maximal functional mobility when moving from the wheelchair. An increased seat-to-floor height allows level or downhill lateral transfers, which have been shown to decrease upper extremity muscle effort.⁷¹ Sit-to-stand transfers are also improved with seat elevation as lower extremity muscles have a biomechanical advantage from a raised seat height. A literature review⁷² confirmed that performance of sit-to-stand transfers is strongly influenced by the seat height. Seat elevation also plays a role in minimizing the risk of upper quadrant musculoskeletal injury and discomfort for wheelchair users. Increased height in space minimizes the frequency of overhead reaching, which has been implicated as a contributing factor in shoulder pain⁷³ and shoulder muscle load.⁷⁴⁻⁷⁶

Wheelchairs that allow passive standing have some similar advantages to seat elevation. However, when considering standing for the client with SCI, potential risk for lower extremity fractures, skin compromise, and hypotension must be carefully evaluated. In general, wheelchairs that allow alternative positioning do not preserve optimal seated postural support.

Power-elevating leg rests (ELRs) are another feature that can be beneficial to the client with SCI. ELRs can be operated either simultaneously with or independent of power tilt and/or recline. When used in conjunction with recline, additional increased surface area is provided for pressure distribution, but increased shear forces result

unless tilt in space is also incorporated. Specific attention to lower extremity range of motion is critical when using ELRs in any wheelchair system. If the leg rest is elevated beyond the user's available hamstring length, the individual will shift into a posterior pelvic tilt to relieve excessive muscle tension. When using ELRs for management of lower extremity edema, they should be interfaced with the power tilt function so that the legs can be positioned above the heart to facilitate fluid management.⁷⁷ Use of power ELRs should be judicious as they are heavy, may increase overall wheelchair length, and may create additional maintenance requirements.

Prescription of a power system includes critical attention to the drive control, in addition to power base and seat selections. The comprehensive client evaluation will provide key information relative to best options for drive control selection. While it is beyond the scope of this chapter to review the multitude of joystick and alternative specialty control options, the correlation between power wheelchair operation and seated posture must be emphasized. In order for the individual with SCI to be successful using any potential drive control—whether by upper extremity, head, oral, or other physical function—postural alignment and support must be addressed first. Providing the individual with an appropriate seating system with posture optimized will allow optimal functional performance for using power controls. Additionally, proper seating is likely to decrease the risk of musculoskeletal discomfort and injury that is linked to repetitive, sustained activity such as that required for operating a power wheelchair.

Overview of Wheelchair Configuration Recommendations and Considerations

The final configuration for both power and manual wheelchairs is determined by selecting the features of the wheelchair and specifying the measurements and angular setup. Table 8-2 provides some recommendations and considerations for the wheelchair configuration for the client with SCI.

Power Versus Manual Decision

The decision to prescribe power mobility for the acutely injured individual with SCI should be made very thoughtfully, and the use of power should be judicious in any case of incomplete SCI. In the case where the use of power is obviously required, the selection of drive control (e.g., selecting sip and puff versus facilitated hand driving) should be made with just as much care. Because there is always the potential for improved function due to neuroplasticity, the individual should be given every opportunity to move functionally in biomechanically appropriate ways. Decreased use promotes learned nonuse⁷⁸ and, more importantly, the establishment of the habit of compensatory patterns of movement. Sometimes

the compensatory function is actual dependence on assistance from another, and this can be a vicious cycle if the caregiver enables dependency.

Motor learning literature suggests the idea that new motor skills are acquired through a process of practice, with error and internal correction, with mastery after generalization to varied environments.⁷⁹⁻⁸¹ Balance after SCI is a new motor skill because there is a new neurologic platform. It is very important not to oversupport or overimmobilize an individual in the early period post-SCI. Minimal equipment with dynamic challenge will optimize facilitatory situations. Of course, care must be taken to avoid fatigue and deterioration of function. A progressive seated activity schedule or alternative positioning can help avoid this issue.

The case of the individual with newly acquired incomplete tetraplegia, especially with central cord syndrome, is an example of a circumstance in which power mobility should be avoided. Facilitation of lower extremity activity with foot propulsion mobility will increase endurance and strength of the lower extremities and set up better potential for independent transfer, functional standing, and perhaps walking. Foot propelling a manual wheelchair creates dynamic balance challenge. Trunk control is especially crucial to those with limited or no upper extremity function. Dynamic manual wheelchair activity facilitates trunk stability.

There is no evidence to support the idea that power wheelchairs will prevent musculoskeletal pain after SCI. While there is evidence that there is a high prevalence of pain in wheelchair users,⁸²⁻⁸⁵ many studies have shown that there is no identifiable association between pain and the type of wheelchair used (power versus manual). Indeed, studies suggest that among persons with SCI there is a higher prevalence of pain in persons with tetraplegia,^{82,86,87} who are more likely to use power mobility. Evidence supports the belief that optimized postural support in an ultralight manual wheelchair and attention to biomechanics of wheelchair propulsion, in terms of both wheelchair setup and propulsive stroke training, is protective to the upper extremities.⁶ Body weight is also a key issue. Lack of basic low-level maintenance exercise will promote weight gain, and increased body weight is associated with more musculoskeletal pain and functional compromise.⁸²

The decision to use power mobility should be made based on functional need. If the individual in question has the ability to transfer independently and can drive a vehicle, he or she will likely be better served with manual mobility. In the situation where the individual is dependent in transfers or cannot drive, he or she may be better served with power mobility. Most persons with C6 level injury without comorbidity can successfully master both transfers and driving; therefore, manual mobility is recommended for acutely injured individuals with injury at this level and below. The functional ability of those persons discharged in manual mobility is often increased

Table 8-2

Seating the Client with SCI: Wheelchair Configuration Recommendations and Considerations

Frame Parameter Key Issues	General Recommendations	Considerations
<p><i>Seat and Back Widths</i> Too wide → inadequate postural control</p> <p>Too narrow → may create skin compromise, provide inadequate support, or cause a postural shift</p>	<p>Snug fit without causing adverse pressure at trochanters or posterolateral ribs.</p> <p>Body measurements at pelvis, hips, knees, and trunk must be considered. Frontal plane alignment and flexibility must be incorporated in width selection.</p> <p>Armrests with panel or rigid clothing guards (manual wheelchairs) can assist with postural control and protection of soft tissue at hips.</p> <p>Consider clothing bulk relative to seasonal differences, but avoid excessive widths: provide education for clothing selections, If aftermarket backrest is specified, ensure that the backrest frame width is sufficiently wide to accommodate it.</p>	<p>Excessive seat and/or back widths contribute to postural deformity as the body may shift to fill extra space.</p> <p>If a discrepancy exists between body measurements for seat and trunk widths, prescribe separate/independent seat and back widths.</p> <p>Seat width correlates to overall chair width, which must be considered relative to environmental access.</p> <p>Some manual chairs are available with a tapered seat (front more narrow than rear). Tapered seats may allow improved leg positioning and increase environmental access.</p> <p>For some power chairs, the space available between the armrests is greater than the actual seat width measurement. Consider actual space available between armrests when selecting seat width.</p>
<p><i>Seat Depth</i> Too long → posterior pelvic tilt</p> <p>Too short → inadequate support</p>	<p>Appropriate seat depth should provide support for the pelvis and posterior thighs, with adequate space remaining between seat upholstery and the posterior knee. "Adequate" depends on functional ability: the dependent person can have less space, an independent person with full hand function requires ~2 inches, and an independent person with impaired hand function needs more space.</p> <p>Specific attention to upper leg lengths, lower extremity range of motion measures, and sagittal plane posture and flexibility is necessary.</p> <p>Seat depth selection must be considered relative to the front frame or footrest angle. Knee flexion position on front frame or footrest is important. Increased knee flexion typically requires a shorter seat depth.</p>	<p>A common mistake is seat depth that is too long. Excessive seat depth is a direct cause of postural compromise, with facilitation of a posterior pelvic tilt.</p> <p>Excessive seat depths also increase overall frame lengths, which negatively impacts accessibility.</p> <p>Seat depths that are too short provide inadequate support under posterior thighs, which may increase pressure under the pelvis.</p> <p>Short seat depths may interfere with transfers secondary to a decreased support platform. Seat depth (upholstery or solid seat) may be prescribed independent of the frame length (i.e., shorter seat on longer frame).</p> <p>Backrest selection and orientation impacts actual seat depth. Installation of aftermarket backrest may increase or decrease the available seat depth, which impacts support, posture, and chair performance.</p>

Continued

Table 8-2
Seating the Client with SCI: Wheelchair Configuration
Recommendations and Considerations—cont'd

Frame Parameter Key Issues	General Recommendations	Considerations
		<p>An asymmetric seat depth should be prescribed for true upper leg length discrepancies or apparent asymmetric upper leg lengths that are related to fixed deformities, such as pelvic rotation or a dislocated hip.</p>
<p><i>Seat Slope</i> Determined by the difference between front and rear seat-to-floor heights divided by the frame depth</p>	<p>Information from the mat evaluation and empirical trials is <i>critical</i> for determining optimal seat slope for postural support.</p> <p>As a general rule, the greater the degree of trunk muscle paralysis, the greater the degree of seat slope to substitute for trunk instability (i.e., with a 16-inch seat depth and extensive trunk paralysis best with 3 to 4 inch front to rear difference vs. intact trunk 1 to 2 inch difference) although highly variable. Seat slope has significant impact on postural alignment.¹⁴</p>	<p>Seat slope and backrest configuration must be addressed in concert.</p> <p>Transfers may be impacted by increased seat slope. Therapists must be competent in teaching transfer techniques from sloped seats.</p> <p>Increased seat slope does not increase interface pressures at the sitting surface.³¹</p>
<p><i>Front Seat Height</i> Front seat height must be considered relative to rear seat height to achieve desired seat slope for postural support.</p>	<p>Must allow appropriate clearance under tables and desks while also allowing adequate clearance under footplate for ground clearance.</p> <p>Consider seat height relative to transfers and vertical position in space.</p> <p>Lower leg lengths, range of motion, footrest position, and cushion heights must be incorporated when determining ideal seat-to-floor height.</p>	<p>Must consider front seat heights relative to driving a vehicle from the wheelchair as clearance under steering column is critical.</p> <p>Front seat height configuration requires attention to frame design, caster diameter, caster fork length, and caster stem length.</p>
<p><i>Rear Seat Height</i> Must be considered relative to front seat height to achieve desired seat slope for postural control.</p>	<p>Rear seat height determines the actual sitting height of the individual.</p> <p>For manual wheelchairs, consider rear seat height relative to rear wheel position. With optimized posture and hand at top dead center of handrim, recommended elbow flexion angle is 100 to 120 degrees^{17,48}</p>	<p>For manual chairs with suspension, consider the impact of suspension on rear seat height when the suspension is loaded. Is rear seat height altered when the suspension system is loaded? Is rear seat height compromised as suspension system ages? Rider body weight changes may result in compromised positioning.</p>
<p><i>Backrest Angle</i> Backrest angle must be considered relative to seat slope as the interaction between the seat and back significantly impacts postural support.</p>	<p>Findings from evaluation and empirical trials indicate optimal back angle position.</p> <p>The available range of motion at the hip must be considered when determining back-to-seat angle.</p> <p>Back angle must also be considered in conjunction with backrest height</p>	<p>Backrest angle can either be adjustable posterior (recline) and anterior or may be a fixed welded angle.</p> <p>Backrest position posterior to vertical may facilitate a posterior pelvic tilt. Adequate lumbar support must be incorporated to support a neutral pelvic position.</p>

Table 8-2
**Seating the Client with SCI: Wheelchair Configuration
 Recommendations and Considerations—cont'd**

Frame Parameter Key Issues	General Recommendations	Considerations
<p><i>Backrest Height</i> Backrest height must be considered in conjunction with backrest angle.</p>	<p>Height of backrest is determined based on prioritization of postural support needs and upper extremity function.</p> <p>Should be high enough that pelvis and trunk are well supported, and low enough to allow normal thoracic extension over the backrest. Back height should not inhibit trunk motion (unless desired) or upper extremity function.</p> <p>Backrests in power-tilt and recline systems must be high enough to provide adequate trunk support when reclined. Central support is the most critical so that the individual is not resting solely on the headrest; contoured relief for scapulae can be incorporated when elbow blocks are provided to support arms when seat is tilted.</p>	<p>The reclined (posterior to vertical) backrest position is overprescribed in individuals with SCI. Individuals with low cervical injuries and those with paraplegia with neutral postural alignment often do well with a vertical backrest that provides lumbar and midtrunk support and allows full scapular and shoulder motion.</p> <p>In manual wheelchairs, a reclined backrest requires that the rear wheel be in a more rearward position, which negatively impacts UE propulsion mechanics.</p> <p>Consider the influence of rear suspension on back angle. When the suspension is loaded, does the back angle shift toward posterior? If so, the backrest angle should be anterior prior to loading.</p> <p>Available in adjustable or fixed heights.</p> <p>A common mistake is positioning the backrest too high. A high backrest contributes to increased thoracic kyphosis, which consequently contributes to a posterior pelvic position, protracted scapulae with the humerus forward in the glenoid, and cervical hyperextension.</p> <p>Avoid positioning the back height immediately above or below spinal stabilization rods as hypermobility at that segment may be facilitated and/or discomfort may result.</p> <p>High backrests must have appropriate contours to allow normal spinal curvature.</p>
<p><i>Front Frame or Footrest Drop Angle</i> Impacts leg position and overall frame length</p>	<p>Configuration or selection of the front frame or footrests must be considered relative to seat slope and front seat-to-floor height.</p> <p>Postural presentation, knee, and ankle range of motion and spasticity must be considered.</p> <p>Consider angle selection relative to overall chair length, which impacts environmental access and chair maneuverability.</p>	<p>In chairs with adjustable seat slope by the rear axle position, alteration of the seat slope alters front frame or footrest angle relative to the floor.</p> <p>A front frame or footrest angle that is closer to vertical requires increased knee flexion. This may be beneficial for inhibition of extensor spasticity if adequate range of motion is available.</p> <p>Front frame or footrest angle also must be considered relative to stability of the</p>

Continued

Table 8-2
Seating the Client with SCI: Wheelchair Configuration
Recommendations and Considerations—cont'd

Frame Parameter Key Issues	General Recommendations	Considerations
		front of the chair. With feet positioned farther in front of the frame or base, a longer lever arm creates forward instability. Caster position relative to the front frame or footrest is also important for addressing forward stability.
<i>Footplate Height</i>	<p>Determine appropriate vertical position relative to the front seat height and ground clearance needs.</p> <p>Lower leg lengths as well as ankle position and range of motion must be considered.</p> <p>Cushion height must be incorporated when determining footplate height.</p> <p>Footplate height is directly related to front frame or footrest angle. For the same lower leg length, a more vertical front frame or footrest angle decreases footplate distance from the floor.</p>	<p>The angle of the actual footplate must be considered relative to the height off the floor. Often, footplates positioned to accommodate plantar flexion contractures increase the actual length required to support the foot, thereby decreasing distance for ground clearance.</p> <p>Footplate position is based on individual needs and personal preferences. However, lower ground clearance requires wheelie mastery in a manual wheelchair and may inhibit rough terrain clearance in a power wheelchair.</p>
<i>Armrest Height</i>	<p>Posture in the sagittal plane must be optimized prior to determining armrest height.</p> <p>Armrests should be positioned such that the elbow and forearm are supported while facilitating a neutral position of the humerus in the glenoid fossa.</p>	<p>Armrests that are too low will allow shoulder subluxation in individuals without a fully innervated or weak rotator cuff.</p> <p>Armrests that are too low facilitate trunk flexion with kyphosis, scapular protraction, forward humerus and cervical hyperextension.</p> <p>Armrests that are too high may cause subacromial impingement or undue pressure on elbow.</p> <p>A manual wheelchair configured as an orthotic device provides appropriate postural support. The armrests are not needed for balance or support and can be eliminated.</p>

at 1 year post-injury, whereas the functional ability of those discharged in power mobility will often decline.

The decision to *change* to power mobility at some point during the life of an individual with SCI should be based on individual medical and functional reasons. Functional limitations tend to accrue with aging and health decline; this is true in the general population and may be magnified in the SCI population. It is important

to assess how the current functional ability is impacting participation. If limitations begin to interfere with social roles, then there may be a domino effect of increased social isolation and declining physical function. However, it is important to recognize that many people will see the move to power as symbolic of their decline in ability or an increase in disability, a "giving in." For some long-term manual wheelchair users there is a

certain pride in their ability to be independent in their mobility without power.

The decision to transition to a power wheelchair is multifaceted, and a thorough assessment with empirical trials should be performed. The change to power may require a change of vehicle, changes in the home environment, and changes in some functional movement strategies. However, if the functional benefits of power mobility outweigh these detriments, then the changes can be successfully made. An example of a functional benefit is propulsion speed, or velocity. The average minimum speed necessary to safely cross a street intersection is 1.06 m/s.⁸⁸ If the individual cannot consistently propel a manual wheelchair at this minimal threshold despite the provision of appropriate equipment and optimal propulsion techniques, power mobility may be indicated.

New power wheelchair designs are smaller in overall width and turn radius, so often there are fewer environmental differences than might be expected. If the individual is well seated and comfortable in the manual wheelchair, then attempts should be made to replicate the sitting position in the new power equipment. Because of the multifaceted nature of this change to powered mobility and the potential for an emotional resistance to it, the process may take 6 months to a year. Generally, a slower, sequential approach will create the more positive outcome.

The Seating Interface

The selection of the cushion and backrest plays a significant role in contributing to the success of a mobility system for the individual with SCI. The cushion and backrest provide the direct interface between the individual and the mobility base. For this reason, the cushion and backrest combination are referred to as the seating interface. When the seating interface is appropriately selected and configured, the individual's ability to function from a wheelchair is optimized. While there are a myriad of seating interface products available, the components to be tested in empirical trials can be narrowed and final selection optimized when the individual's needs and the goals of the overall seating system are carefully considered. Impaired function as a result of paralysis, postural deformity, impaired sensation, altered skin integrity, and issues with pain and discomfort create challenges for long-term successful seating interventions. Results from a comprehensive evaluation will guide determination of appropriate seating interface products to be included in trials. Typically, the key goals for the seating interface for an individual with SCI are to (1) provide necessary postural support for proximal stability, (2) promote skin protection, (3) provide comfort, and (4) encourage optimal function. The relative priority for each of these goals is specific to each individual and must be considered when determining which seating products may be most appropriate. Skin protection is always a high

priority for the wheelchair user with SCI because of the high risk of skin compromise due to the nature of the disability. However, when providing products that promote skin protection, it is essential to consider needs for postural support, comfort, and function. An understanding of the key features and considerations for different types of cushions and backrests and the necessary interaction between the two will assist the therapist in matching equipment to the client's individual needs and priorities.

Wheelchair cushions and backrests are commercially available in a broad range of materials, shapes, sizes, and configurations. They vary in degree of support and skin protection provided and span a wide spectrum of shapes and contour, from standard to highly customized. Without an attempt to individually review specific equipment, a discussion of the unique aspects of different types of products will guide the therapist's thought process for determining seating interface solutions to best meet the needs of an individual with SCI. In all cases, selection of the seating interface is unique and specific for each person.

Two key factors to consider when evaluating various seating interface products are materials and shape. The materials from which the product is constructed, combined with the shape of a given product, will guide determinations for postural support, stability for function, comfort, pressure and shear management, airflow and temperature characteristics, weight, and durability. Materials and shape also dictate how the interface product will function for the individual. The adjustability of cushions and backrests will differ depending on the materials used. It is also necessary to clearly understand and address the interface of the cushion with the backrest and the interaction of both with the mobility base. Selection of appropriate products combined with the proper orientation on the wheelchair is necessary for optimal outcomes when seating the individual with SCI.

Cushions

There are two primary approaches to cushion design for skin protection: the distribution of pressure across the sitting surface and the off-loading of high-risk bony prominences. Pressure distribution requires that the cushion materials and shape deform under load, which allows pressures to disperse across the entire sitting surface. A cushion designed for off-loading requires a firm material and specific shape that does not change under load in order to achieve the desired redirection of sitting forces.

A third, less common, design approach is the dynamic cushion. Alternating inflation cushions use a battery-powered motor that provides intermittent inflation to a series of air bladders. The air bladders are inflated and deflated sequentially, with the aim of decreasing the duration of sitting pressures to allow improved blood flow to the tissues of the sitting surface. While pressures

on dynamic cushions have been measured to be very low during the deflation cycle, pressures during the inflation cycle increase significantly.⁸⁹ The benefit of dynamic cushions is intermittent reduction of pressure at different regions of the sitting surface. The significant concerns with the dynamic cushions are lack of seated stability, difficulty providing necessary postural supports, maintenance of the cushion, maintenance of the motor and battery, and increased weight added to the overall seating system. Koo et al. found that pressure management characteristics of an alternating inflation cushion were not as good as those of either air inflation or polyurethane foam cushions.⁹⁰

Cushion selection should be highly individualized for each wheelchair user. A fundamental understanding of cushion materials and properties is necessary to guide clinical recommendations for cushion prescription. A wide variety of material is used in cushion construction. While some cushions are constructed of a single type of material, as in the case of single-density foam cushion or an air inflation cushion, many products use a combination of materials to achieve the desired outcome. Materials commonly used either alone or in combination include open cell foam, closed cell foam, viscoelastic foam, elastomer gels, viscous fluids, air, and flexible matrix thermoplastics.

Foam is a lightweight cellular material is characterized by density (weight per unit volume) and stiffness (resistance to deformation). Different types of foams are used for different applications based on the density and stiffness characteristics. For example, foams that are very stiff are typically used for base materials and for specific applications where the foam must hold its shape under load. Viscoelastic foam has both elastic and viscous properties that dictate that the foam will deform under load, and to the original shape when unloaded. The time required for the foam to return to the original shape is dependent upon properties of the foam (which change as the cushion ages), the amount of load, and the amount of time the load was in place. The benefits to foam cushions are that they are typically lightweight, are available in a wide range of thickness and contour, and require little maintenance. However, some foam cushions are difficult to keep clean, will retain odors, lose contoured shape under load, and require frequent replacement due to deterioration of materials. Foam cushions have been found to produce higher temperatures⁹¹ as well as increased relative humidity associated with increased temperature.⁹² Cushions constructed of a flexible honeycomb matrix formed by a fusion bonding process function in a manner similar to foam cushions. The thermoplastic cushions are lightweight, allow airflow for temperature and moisture management, require little maintenance, and are easy to clean. The flexible honeycomb matrix provides increased shear management. Incorporation of fluids in cushion fabrication is common.

A wide variety of viscous fluids, gels, and pastes, as well as water, are incorporated into cushion construction. While these fluids vary significantly from cushion to cushion, the general aim is to use the fluid as a means of distributing pressure around and away from bony prominences. Cushions that incorporate gels, pastes, or water typically provide elements of both postural support via a firm base and skin protection via load distribution. However, fluid cushions are typically heavier than foam or air cushions and have been shown to significantly increase humidity at the sitting surface due to perspiration.⁹² The specific heat of a given fluid will influence skin temperature at the sitting surface.⁹³ Water has a high specific heat and is likely to increase skin temperature, whereas air has a low specific heat and therefore is not likely to increase skin temperature.

Air has characteristics similar to fluid and is used in cushions that are commonly prescribed for the client with SCI. Immersion of the buttocks into an air inflation cushion usually provides good distribution of pressures due to envelopment of the sitting surface. When compared to other cushions, air flotation cushions have demonstrated improved distribution of seated pressures.^{94,95} Air inflation cushions typically control shear forces as the individual air cells move with the body. An element of shock absorption is another benefit to the air cushion. The primary concerns with the air inflation cushions are the required maintenance, with risk for puncture or valve dysfunction, difficulty determining and maintaining ideal inflation parameters, and inherent sitting instability. Most air inflation cushions now offer multichamber adjustments to improve postural support for deformity and to offer increased stability.

In addition to the materials used to construct the cushion, cushion shape must also be given critical consideration. When viewing the superior aspect of the cushion (top), cushions range from flat to highly contoured, with most falling somewhere in between. A number of studies have demonstrated that, compared to flat cushions, contoured cushions distribute pressure better⁹⁶⁻⁹⁸ and allow improved functional skills such as reach.⁹⁹ The specific materials used play a key role in the shape as well as the function of a specific cushion. An understanding of what happens to the original shape when loaded by the individual is important. Is the original shape preserved? Does it remain rigid and maintain shape for stability? Or is it compressed to match individual contours (immersion)? Or compressed to the point that protection of bony prominences is compromised? The combination of materials and shape gives the overall specific characteristics of any given cushion. For example, the Jay 2 cushion is constructed with firm, nondeforming closed-cell foam, with specific contours for the pelvis and thighs used as a base support. A fluid and foam overlay over the firm base is used to provide skin protection properties when the client is immersed in the fluid, while preserving the base shape for stability. Understanding the interaction of

materials with shape guides clinical reasoning for cushion trials and selection.

Immersion of the buttocks into the cushion defines the shape that the cushion will assume under load and therefore impacts the function of the cushion. One way to understand the concept of immersion is to think about how far the pelvis and legs will sink into the cushion when the cushion is loaded by body weight and how the cushion reacts to that load. Depending on the cushion construction, the amount of immersion varies widely. An air inflation cushion is designed to allow the body to sink into the cushion, this allows the cushion shape to conform to the body thereby increasing the area over which seating pressures are distributed. A firm cushion with contours is designed to preserve its shape under load, providing postural support. A cushion that has an initial flat shape is typically expected to conform to the body under load, while a firm cushion with highly specific contours is expected to maintain its shape under load so that the body conforms to the shape of the cushion.

When evaluating shapes of cushions, the orientation and degree of cushion contours must be considered relative to the individual client. The findings from a comprehensive client evaluation must be the basis for determining potential appropriate cushions for that individual. Based on the client evaluation, goals for the cushion are determined that will guide trials and selection. In general, an individual who sits with neutral alignment and symmetric orientation in all planes is most appropriately fitted with a cushion that will match that symmetry, whether by existing symmetric contours in the cushion or by immersion of the symmetric body into the cushion. Conversely, postural correction or accommodation requires a supportive material that will not deform under load. An individual who sits asymmetrically and has flexibility to tolerate correction toward neutral alignment requires a cushion that will provide the supportive correction and will maintain its shape under load so that the individual does not shift toward asymmetry. At the other end of the spectrum is the individual who sits asymmetrically and who does not have flexibility available to assume a more neutral orientation. In this case, the individual is usually best served with a cushion that accommodates the existing postural asymmetry, yet provides support to prevent further progression of the deformity. It is the composite angle of the wheelchair frame configuration and the cushion contours that dictate the posture and seated stability; therefore, care must be taken when prescribing new equipment. Trials are critical for integrating a new cushion with existing equipment.

Backrests

Backrest selection and configuration requires the same critical thought as that required for cushions. Based on the client evaluation and assessment, goals for the overall

seating system will be identified and will guide clinical problem solving for the wheelchair backrest as well. Like cushions, backrests vary widely in materials, shape, and degree of adjustability and customization. Selection and orientation of the cushion and backrest must be coordinated in every seating system. The backrest must interface appropriately with the cushion and the mobility base in a specific orientation to provide support, comfort, and skin protection while promoting maximal function in the wheelchair. If the backrest is not addressed as an integral interaction with the cushion, the specific qualities of the chosen cushion may be lost. If the backrest is not optimally orientated relative to wheelchair, the performance of the entire system may be compromised.

Like cushions, the materials, construction, design, and functionality of backrests vary significantly for both manual and power wheelchairs. The broad categories for backrests are soft sling, planar, contoured, and custom. Backrest materials and shape will determine ability to provide postural support, stability for function, comfort, pressure and shear management, airflow and temperature characteristics, weight, and durability. Backrests have not been studied extensively in research settings.

Sling upholstery is the standard default backrest for most manual wheelchairs and some power wheelchairs. The advantages to sling upholstery are that it is low maintenance, low cost, and readily available. These backrests are also lightweight and add no bulk to the wheelchair, so that the chair is easier to transport. The greatest disadvantage to standard sling upholstery is that the material has a tendency to stretch over time, which can result in the compromise of postural support. An excellent upgrade from the standard sling upholstery, now available from most manufacturers, is the padded nylon sling that is tension adjustable by straps positioned posterior to the backrest. The series of tension-adjustable straps allow a fine-tuned fit to provide positional support for the pelvis, lumbar spine, and trunk. Additionally, maintenance of the strap tension preserves orientation of the backrest between the back posts and negates the effect of material stretch over time. It is critical that the adjustable tension backrest be appropriately padded with quality materials to avoid skin irritation and bruising from the straps. Several sling-style backrests also offer subtle lateral supports as well, which can assist with pelvis and trunk support. When properly configured, the adjustable-tension sling upholstery can be an appropriate device for the wheelchair user with SCI.

Linear backrests are commonly used in wheelchair configurations, particularly power wheelchairs. Linear backrests are either flat or curved, with a minimal lateral contour. They are typically constructed of a solid, strong base material such as plywood, metal, or a plastic composite and covered by a foam overlay. Subtle customization of the backrest shape is possible with the addition of lumbar padding and articulated lateral supports. Linear backrests are durable, and the provided

strength is reliable for high-load situations such as that needed with a power tilt pressure relief. The linear backrests typically allow mounting of headrests and lateral positional supports. Installation of a linear backrest will usually result in a loss of effective seat depth. Because of the fixed configuration of the solid base, the linear backrest is most appropriate for those with neutral, symmetric sitting postures when appropriate trunk contours are provided, such as a lumbar support. Because human anatomical alignment is curved, not linear, most clients with SCI will be better served with a contoured backrest.

Contoured backrests are available in a wide range of material, size, shape, and adjustability. Contoured backrests are mounted to the back canes with a hardware interface. Some contoured backrests are lightweight, such as those constructed of carbon fiber, aluminum, or plastic composites. Others are quite heavy, especially when higher weight metals are used or articulation is incorporated in the backrest. When evaluating the weight of the backrest, it is imperative to consider the weight of the mounting hardware as well. Most contoured backrests have a symmetric lateral shape, with the degree of lateral contours highly variable in both height and depth. Most offer some degree of customization, such as addition of lumbar and trunk contouring by foam supports or additional mounted hardware. Many contoured backrests offer a great degree of adjustability in height, angle, and fore-aft positioning on the wheelchair, which is an advantageous feature for this type of backrest. Because the contoured backrests inherently have a firm, symmetric shape, they are appropriate for those individuals with good flexibility who can achieve and maintain trunk symmetry while sitting. Individuals who sit with trunk asymmetry in multiple planes may require a custom-molded backrest.

Custom-molded backrests are effective for providing specific postural support by strategic and precise contact with the trunk. Most custom backrests are constructed from an impression or mold of the individual in optimal orientation. When fit properly, the custom backrest provides the necessary support for posture and function. The increased contact area inherent to a custom backrest preserves skin integrity by improved pressure distribution and decreased shear forces. Because of the individualized support provided, the molded backrest functions most like a stabilizing orthosis, such as a TLSO (thoraco-lumbar-sacral orthosis, or "body jacket") used to stabilize the spine following acute SCI. A stabilizing orthosis is specifically intended to restrict or control movement. While the restrictive control is desirable in some seating cases where a molded system is indicated, it is imperative that the control provided does not impair function. Custom-molded backrests are most appropriate for individuals who require precise postural control to either correct a significant postural asymmetry or to prevent progression toward further deformity. Key considerations when evaluating custom-seating

products are weight, materials used, interface with the cushion and mobility base, availability of adjustments and modifications, and relative cost.

Integration of the Cushion and Backrest

When evaluating seating interface products (cushions and backrests) for an individual with SCI, the availability of various sizes, adjustments, and modifications of a given product is important. Because the fit of the overall seating system is highly individualized and customized for each client, the seating interface products must allow for that individualized fit. Relative to cushion sizes, it is important to know that it is standard in the rehabilitation industry to refer to cushion dimensions as width first, followed by depth. For example, an 18 inch by 16 inch cushion is 18 inches wide and 16 inches deep, which is completely different from a cushion that is 16 inches by 18 inches. Backrest measurements are referenced first by width, then by height. Thus, a backrest that is 16 inches by 14 inches is 16 inches wide and 14 inches high. Some products are available in a selection of standard sizes only, while others are available in a wide range of combination sizes or can be modified by the manufacturer, or in the clinic, for a specific size. In most cases, it is not acceptable to compromise by using a standard dimension cushion as a default. For example, if the client evaluation reveals that the individual is best served with a 15-inch seat depth, the cushion should also be 15 inches deep. Compromise with a 16-inch-deep cushion may have a negative effect on seated position or function while compromise with a 14-inch-deep cushion may compromise positional support and skin protection. Similarly, if it is determined that an individual is best served with a 14-inch backrest height, compromise with use of a 16-inch backrest height is likely to result in impaired support and function.

The interaction of the cushion and backrest requires that the two components be addressed, both together and individually. The cushion selection and the backrest selection must complement each other. The cushion offers the platform for inferior aspect of the pelvis and posterior legs. The backrest is the support for the posterior pelvis and trunk. The cushion and backrest must be selected and oriented in such a way that there is an appropriate transition between the posterior aspect of the cushion and the inferior aspect of the backrest such that the seated individual is supported in the desired anatomical position. A compromised backrest orientation will negate the supportive qualities of the cushion.

Conversely, the backrest and cushion selections should also be addressed individually as there may be differences in needs between the two. Consider a woman with SCI to illustrate the need for different width in cushion and backrest support. Because of the natural female shape and distribution of body weight, a woman may require a backrest that is significantly more narrow

than the cushion and wheelchair width. When indicated, the more narrow backrest must be provided. If not, she is likely to develop a postural asymmetry as a result of sitting with inadequate trunk support from a backrest that is too wide. Similarly, an individual with a pelvis narrower than his trunk must have a cushion that fits the pelvis, not the width of the backrest. In the case of an individual with flexible postural asymmetry, the process is to first address the pelvic obliquity. The individual may require a cushion that is adjustable, modified, or even customized in order to provide the necessary support under the pelvis. After the pelvis is addressed with an appropriate cushion, trunk symmetry is often achieved, which allows the individual to use a standard symmetric backrest. Only if more support is required would a modified or custom backrest be considered.

With contoured products, it is imperative to understand that the dimensions of the product must be fit to the client first, then to the wheelchair. Consider an obese individual with SCI to illustrate this point. With increased adipose tissue, the actual size of the skeleton does not change, but the overall body width does. Therefore, a man with a pelvis that is 16 inches wide using a contoured cushion requires a 16-inch-wide cushion so that the anatomical contours of the cushion match the body dimensions. However, since the adipose tissue exceeds the 16-inch width, the necessary wheelchair width may be 18 inches and the adipose tissue will exceed the 16-inch-wide cushion. In this case, the best solution is to prescribe a 16-inch-wide cushion custom modified to extend laterally for support of adipose tissue and to fill the space for the 18-inch wheelchair width. If an 18-inch-wide contoured cushion is used for a 16-inch-wide pelvis, the pelvis will be unsupported by the lateral cushion contours, which may result in skin compromise and lack of postural stability. This approach is also appropriate for an individual who sits with extreme pelvic obliquity and associated lateral trunk curvature. Positioning of a cushion under the pelvis may require a lateral extension on the side of the obliquity to fill the space for the required wheelchair width. With the challenges associated with the seated client with SCI, it is often necessary to adjust, modify, or customize a product to best meet the individual's needs. The availability and ease of customization, whether by the manufacturer or in the clinic, is a key consideration for equipment selection.

The selection as well as the orientation of interface products relative to the mobility base carries significant implications when seating the client with SCI. Each product must be considered not only relative to the interface with the client, but also how one product impacts the outcome of the overall system for the individual. For example, the height or thickness of the cushion plays a key role in wheelchair seat-to-floor height, footrest height, armrest height, clearance under tables, and transfers to varied surfaces. The orientation of the backrest must be considered relative to several aspects of the

overall seating system. The angle and height of the backrest has implications for stability in a manual wheelchair. A backrest that is reclined causes a manual wheelchair to be unstable to the rear. A reclined backrest also allows the pelvis to rotate posteriorly, which shifts the pelvis forward on the cushion and creates an increased midthoracic kyphosis with cervical hyperextension. Ideally, the backrest must be high enough to provide adequate pelvic and lumbar support, yet low enough to allow normal thoracic curvature over the top of the backrest. This backrest orientation will maximize upper extremity function for propulsion and daily living tasks. A backrest that is too high compromises both posture and function. In a power wheelchair with a power tilt system, the backrest height must be high enough to support the individual when tilted. For power tilt users with shoulder function, the backrest should be shaped such that the center provides support for tilt while the lateral shape allows appropriate space for scapular mobility.

Pressure Mapping

Interface pressure mapping (IPM) is a clinical tool that, when used correctly, adds valuable information for seating interventions. IPM provides objective measurement with visual representation of the pressure between two objects or surfaces. In wheelchair-seating assessment, IPM measures the force applied by the client's sitting surface to the cushion and/or by the client's trunk against the backrest support.

The use of IPM has gained attention for seating the client with SCI due to the prevalence of pressure sores in this population. One goal of an appropriately configured seating system is to provide skin protection. For the client with SCI, evaluation and management of seated pressures is a mandatory consideration when addressing comprehensive seating system needs. A correlation between increased seated interface pressures and incidence of pressure ulcers has been demonstrated in published studies.^{96,100}

An IPM system consists of a computer and monitor, the pressure-mapping software, the data collection sensor pad(s), an electronics unit, and a power source. The sensor pad is placed between the seated individual and corresponding surface. A digital color representation of interface pressures across the contact surface is displayed on the monitor. Software display options exist for viewing the pressure data, such as 2-dimensional with color isobar, 3-dimensional pressure contour, or with a numeric grid that reports the numeric pressure reading for each sensor cell. Additionally, pressure distribution histograms and pressure-versus-time graphs are available. The center of gravity can be displayed, as well as statistical information regarding average pressures across the sensor pad, peak pressure, and total contact area. The sensitivity of the sensor pad can be adjusted for more

discerning evaluation. Some IPM systems allow wireless programmed recording of IPM data that is downloaded for evaluation once the recording session is complete. Ideally, pressure mapping in dynamic conditions should be incorporated into clinical practice as investigations have shown that seated pressures increase during wheelchair propulsion.^{101,102}

IPM is commonly used for relative comparison of seating interventions and equipment assessment. Following a comprehensive client evaluation, changes in wheelchair configuration and/or cushion trials are attempted, with the goal of improving postural alignment and/or distribution of pressure. Since neutral, symmetric sitting posture typically best distributes pressure, seating interventions to optimize posture should precede pressure management strategies. Published research has demonstrated that interface pressures are influenced by seated postures.^{62,90} Typically, a baseline IPM measurement is taken and compared to measurements following adjustment of the seating system (an *intervention*) by an experienced therapist. In most cases, the desired result is to decrease pressure at a region of concern or to ensure that pressures have not been increased. IPM is beneficial for measuring the presence, location, and distribution of pressure, and it is also valuable for demonstrating the absence of contact or complete off-loading of a body surface. IPM is useful for evaluating the influence of specific wheelchair configuration adjustments, as well as the client's pressure picture on different cushions and backrests. When combined with other essential assessment factors such as comfort, postural support, functional skills, and skin inspection, IPM data is helpful in assisting with equipment selection and configuration. It is recommended that a clinical IPM protocol be adopted for the collection and interpretation of data. A standard international protocol for IPM would assist with identifying reliable practices for collecting and interpreting IPM data, but this is not currently available.

IPM is also a powerful education tool. It is particularly useful when used as a component of client training for effective pressure relief. With the client seated on the sensor pad, he or she can watch the pressure map display on the monitor for visual feedback to determine the effectiveness of a pressure relief effort. IPM is valuable for therapist education as well. When used properly, IPM is used to confirm or deny a clinical hypothesis. For example, when the hands-on evaluation reveals that a client sits with a pelvic obliquity, higher pressures are expected under the lower ischial tuberosity, which can be confirmed with pressure mapping. The therapist can use IPM in conjunction with palpation to confirm postural alignment and the location of bony prominences.

IPM can also be used to guide modifications to existing equipment. When the IPM display indicates a high-pressure area for a seated individual, palpation of the sensing mat at its outside margins allows a grid to be determined, with markings on the cushion to specifically locate the high-pressure area under the seated person.

This allows the cushion to be modified at the precise problem area, as determined by coordinate markings, once the individual transfers out of the wheelchair.

IPM has several valuable clinical uses; however, the limitations of this technology must be considered as well. Understanding how *not* to use the technology guides the therapist in using pressure mapping as one appropriate "tool."

Pressure Mapping Does Not Stand Alone. IPM serves as an adjunct to the comprehensive evaluation with hands-on assessment, including skin inspection. IPM alone does not provide adequate information to guide clinical decision making.

Pressure Mapping Measures Interface Pressures Only. The sensors measure force applied, in a vertical dimension, by the client to the sitting surface. Key factors that are not measured by IPM are capillary pressure, tissue perfusion, and shear forces.

Pressure Mapping Cannot Substitute for Skin Inspection. Skin inspection is mandatory for all seating evaluations and interventions. If there is an area of high pressure, the skin will redden or have evidence of breakdown at that site. If the pressures are well distributed and there are no areas of excess pressure, the skin will not be discolored. Skin inspection reveals areas of scars from previous skin compromise and surgeries. Palpation of the skin and underlying tissue will reveal alteration of normal tissue integrity that may indicate pressure-related problems beneath the skin.

Pressure Mapping Does Not Substitute for Knowledge of Equipment Options. IPM should not be used to "guess" at a potential seating intervention. Professionals providing seating intervention must possess comprehensive knowledge of equipment options and available adjustments. Identification of specific client needs narrows the field of equipment choices that are then appropriate to be "mapped" for supplemental information.

Pressure Maps Cannot Be Generalized. While IPM adds important information about a specific individual sitting on a particular surface, the information cannot be generalized to other people. The same cushion usually maps very differently under different people because each individual has unique sitting positions, anatomical orientation, and tissue integrity.

Pressure Maps Never Negate the Need for Pressure Relief. Even with the best possible pressure map, individuals with SCI must continue to perform consistent pressure relief with complete off-load of the sitting surface.

Pressure mapping is a valuable tool for measuring interface pressures for the client with SCI. When used judiciously as an adjunct tool in the evaluation and intervention process for wheelchair seating interventions, IPM provides objective information that is useful for decreasing the risk of debilitating pressure ulcers.

Pulling it Together: Evaluation for Seating Systems

Evaluation

Successful seating system prescription requires that a qualified therapist or team of professionals complete a comprehensive evaluation of the wheelchair user. Individuals who may be involved in the evaluation or sharing of information include the client, the family and/or caregivers, the physician, physical therapist, occupational therapist, recreation therapists, and/or other members of the health-care team. Regardless of length of time since SCI, the following information is critical for prescribing a seating system that will result in optimal outcomes.

Medical Background

Pertinent information regarding medical issues can be obtained from medical record review combined with a client interview. Age, length of time since SCI, and American Spinal Injury Association (ASIA) scores with indication of upper motor neuron (UMN) versus lower motor neuron (LMN) damage provide important information. ASIA scores combined with a documented course of rehabilitation and time since injury indicate prognosis for recovery of function. Body morphology—height, weight, and body type—should be investigated relative to preinjury body build and course of weight fluctuation since injury. Individuals typically lose significant weight following the initial injury and often gain weight back to baseline or beyond their “walking weight” following initial rehabilitation. Those with LMN injuries will typically atrophy significantly in their lower bodies in the first several years with SCI. Those who gain weight will often carry the weight in the trunk and upper body, with loss of tissue mass in the buttocks and legs. Current and past medical history should be reviewed with attention to respiratory issues, cardiac function (with review of circulation and blood pressure management), and metabolic disorders. Critical attention must be paid to secondary issues associated with SCI, including spasticity, pain, skin compromise, and orthopedic complications such as heterotopic ossification and hip subluxation or dislocation. The review of past surgical history includes investigation of the extent and nature of spinal stabilization and history of surgical interventions for wound management.

Physical Assessment

A thorough physical examination is mandatory when evaluating for the seating system. The basic clinical evaluation skills learned in entry-level professional programs are invaluable for adding critical information to comprehensive assessment. Passive range of motion (PROM) measures and flexibility testing identify limitations in body motion that can have significant implications for

postural alignment and support in the seating system. Strength evaluation determines which muscles are innervated and available for functional use and which are in need of strengthening. Evaluation of muscle tone and reflexes provides information about optimal orientation in the seating system to inhibit undesired involuntary responses. Assessment of sensation is critical for determining needs for skin protection and tolerance of external supports. Examination of the skin at the sitting surface and trunk details current issues with compromised skin and past issues indicated by scar tissue. Respiratory functional assessment in various positions indicates potential positions for optimal ventilation. Measurements of body dimensions and leg lengths are also specifically considered relative to seating system prescription.

A comprehensive postural evaluation is a key component of the physical assessment. When combined with the physical measurements above, postural presentation indicating the body's reactions to gravity guides the therapist's approach for configuring the seating system as an orthotic device. Observation of the individual in three circumstances is recommended: sitting in existing mobility system, short-sitting on a firm mat with minimized external support, and supine on a firm mat. Transitioning the individual from sitting in the wheelchair to sitting on the mat indicates how the current wheelchair impacts the client's postural presentation. Sitting on the firm mat without support provides information on the body's natural reaction to gravity. While sitting on the mat, we expect an individual with full or partial trunk paralysis to assume a position of posterior pelvic tilt with lumbar and thoracic flexion to achieve stability against gravity. In this position, key information about trunk flexibility into flexion and extension can be assessed with manual contacts and passive movement into available ranges of motion. After sagittal plane current and potential alignment is understood, the extent of frontal plane asymmetry, such as a pelvic obliquity, can be assessed. Observation of the individual's alignment in the supine position eliminates the influence of gravity. Trunk and lumbopelvic flexibility testing in three planes, combined with the passive range-of-motion (PROM) evaluation, indicates the body's ability to assume a neutral postural presentation with manual facilitation. This information is then used to guide initial simulation of seating system configuration to provide control that is needed and can be tolerated in the upright sitting position.

When documenting the postural evaluation, a simple sketch is an efficient way to represent the information gathered from palpation and observation as a supplement to written text. Figure 8-6a-c illustrates schematic examples of how a postural evaluation may be documented. Figure 8-6a illustrates neutral alignment in the frontal plane, which is the desired seating goal; Figures 8b and 8c show pelvic obliquity and a “windswept posture,” respectively, common deviations from neutral postures.

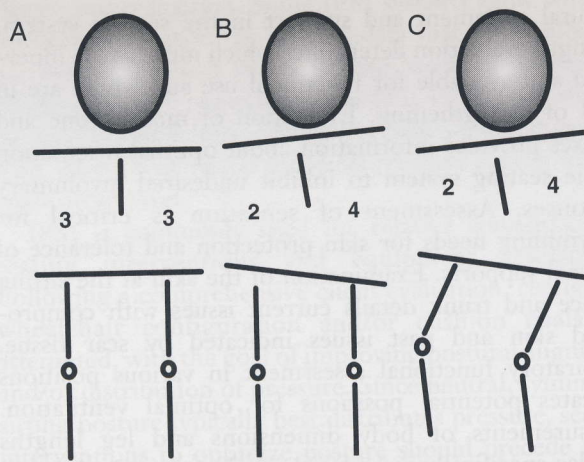


Figure 8-6. Schematic documentation of postural evaluation. In the simple diagram, the circle represents the head, the superior horizontal line represents the shoulders, and the lower horizontal line represents the pelvis. The short vertical line below the shoulder line represents the orientation of the sternum. The numbers indicate the space between the top of the iliac crest and the lowest rib. The actual number references how many of the therapist's fingers fit in that space. The vertical lines below the pelvic line show the alignment of the upper and lower legs. (A) The desired neutral posture, wherein the individual is well aligned. (B) Pelvic obliquity, wherein one hemipelvis is elevated with respect to the other. (C) Windswept posture, wherein pelvic rotation results in malalignment of the legs, trunk, and shoulders.

In general, *correction* is attempted for postural deviations found to be flexible, while *accommodation* is the approach for fixed alignments. There is also an important sequence to postural correction. The sagittal plane must be corrected first. The architecture of the spinal column is such that in a more flexed position there is more medial-lateral play, as well as more play in frontal plane rotation; therefore, improper sequence can result in overcorrection of a frontal plane deviation. It is also critical to understand that there are few postural deformities that are truly fixed, as most will progress with time toward further deformity unless appropriate stabilizing supports are incorporated in the seating system. Whether an individual has had a recent SCI or is a longstanding wheelchair user, the information from the physical examination, including the postural evaluation, is critical for determining ideal seating system parameters. Table 8-3 shows critical physical measures that influence seating configuration.

Equipment Evaluation

Examination of equipment currently being used provides important information relative to the individual's physical presentation. Attention should be directed toward the mobility system configuration, specifically to the seat dimension, seat slope, backrest configuration, and frame design (including front frame or footrest orientation). The cushion and backrest are evaluated for supportive

and protective qualities. The presence of additional external supports provides insight into prior attempts to provide postural stability. The accessories on the existing wheelchair, such as friction-coated handrims or anti-tip bars on a manual wheelchair, may indicate functional limitations. Patterns of wear on wheelchair components and cushions provides key information for the client's typical postural alignment in the wheelchair, functional habits, and mobility strategies. Pressure mapping, described earlier in this chapter, provides objective information regarding body contact with the existing system that can be useful during the evaluation process.

Psychosocial Profile

The wheelchair user's cultural background, cognition, education level, behaviors, preferences, and social support systems (friends, family, caregivers) may carry significant implications for the seating system prescription. Some individuals may have strong preferences for equipment configuration or may have specific requirements based on priorities for appearance or functional needs in specific environments. Others, especially those with more recent SCI or with cognitive impairment, may rely heavily on the therapists recommendations for equipment selections. In all cases, the therapist must respectfully communicate with the individual, allowing the client to participate in the process to his or her comfort level. A thorough psychosocial review will assist with determining appropriate seating system configuration.

Functional Assessment

Discussion and observation of the client's movement strategies indicates the extent of impaired mobility and associated compensations that allow optimal function. Relative to seating needs, the functional exam includes observation of balance strategies and coordination relative to wheelchair propulsion or driving patterns, transfer techniques, pressure relief methods, and self-care strategies such as dressing and bladder management. It is important to investigate functional performance beyond the clinical setting, which gives a more realistic view of the client's situation. For example, frequent transfers to varied heights may impact selection of wheelchair seat heights. Asymmetric repetitive actions, such as consistently reaching toward one side, may have implications for postural presentations such as pelvic obliquity with scoliosis. Observation of movement skills and habits, combined with expectations for functional outcomes based on level of injury and ASIA Impairment Scale (AIS) scores, guides determination of wheelchair needs to encourage optimized function. Additionally, areas for needed education and training can be identified to encourage maximized functional potential while preventing injuries associated with long-term disability.

Table 8-3
Critical Measures that Influence Seating Configuration

Passive Range of Motion Limitation	Component Affected
Hip flexion without posterior pelvic tilt (measure hip only not allowing spine motion)	Need to accommodate range if less than that needed for seat-to-back inside angle (drop the front of seat toward floor whenever possible instead of reclining backrest). Unilateral hip flexion limitation will create a low contralateral pelvis; accommodate the flexion limitation to correct the obliquity.
Hip extension without anterior pelvic tilt (measure hip only, not allowing spine motion). Inside hamstring length with hip flexed at 90 degrees (or intended seat-to-back inside angle).	Accommodate hip flexor contracture to decrease lordotic pull (steep seat slope). Front frame or footrest drop angle should be tighter and placement of pivot point closer (accommodates the hamstring tightness to avoid posterior pelvic tilt).

Environmental Profile

The anticipated various environments in which the mobility system will be used must be thoroughly explored. The climate in which the individual lives may impact the selection and configuration of seating system components. Most individuals with SCI will use their wheelchair both indoors and outdoors. The transitions must be evaluated, as many ramped doorways will have a significant sill or threshold, and landings may have limited space with an outward swinging door. Indoor settings almost always include carpet and tight spaces for wheelchair negotiation. Outdoor terrain includes slopes in all directions, uneven surfaces, and architectural barriers. When prescribing a new wheelchair, it is important to address dimensions and limitations in the home and work settings as well as other places frequented. It is important to ask the individual where he or she spends time in a given week or month.

Transportation

Methods of transportation must also be critically assessed relative to wheelchair recommendations. Functional skills and exploration of whether the individual will use a personally owned vehicle or public transportation must be carefully considered. With personally owned vehicles, some manual wheelchair users will transfer to the driver's seat, independently stow the wheelchair, and drive independently with adaptive driving controls. In some instances the wheelchair will be stowed in a trunk or rear compartment of a vehicle.

Power wheelchair users will require either a ramp or lift to enter and exit the vehicle. Some manual wheelchair users also choose this option. Thus, compatibility between the individual's wheelchair and the vehicle to be used must be considered. Some power wheelchair users

will transfer to the vehicle driver's seat, some will drive the vehicle from their wheelchair, and others will stay in their wheelchair to be transported as a nondriving passenger. Most who use public transportation will stay in their wheelchair and access the vehicle via a lift or ramp. Regardless of the vehicle, when an individual is transported in a wheelchair, proper support in the wheelchair must be provided and an appropriate occupant restraint (vehicle mounted) and wheelchair tie-down system must be used.

Seating system prescription necessitates a comprehensive evaluation for all clients, whether a first-time or long-standing wheelchair user. Those with long-standing SCI typically will provide more comprehensive information and often have firm preferences. While the newly injured individual without significant medical complications typically presents as symmetric and flexible, it is nonetheless important to document the comprehensive evaluation to have a baseline for future follow-up. The first-time wheelchair user can greatly benefit from the education gained during the evaluation process. Discussion of findings, review of available equipment options, and mobility techniques education will empower individuals to understand their body and take responsibility for their choices and actions.

Equipment Selection

Proper selection of a wheelchair requires consideration of the needs of the user, both the postural and functional needs, as well as the demands on the functions of the wheelchair. The postural evaluation provides the information on the orthotic requirements of the equipment. Through the postural evaluation, the therapist can establish the parameters needed for the wheelchair set up.

Clinical decision making about equipment should follow a systematic pathway as represented in the schematic in Figure 8-7. Specifically, the requirements for seat slope, inside seat-to-backrest angle, and the height of the backrest should be determined. This resembles the process of determining what features a lower extremity orthosis must provide to the individual after the examination and gait evaluation. The therapist creates a list of requirements and client-specific needs that must be met by the wheelchair design.

Once the therapist has determined the orthotic requirements of the equipment, this information is combined with the functional demands of the equipment in terms of both mobility and lifestyle function requirements for the individual. At this point, the therapist is ready to select equipment for empirical trials.

The client should only try equipment that is appropriate. This means that a list of equipment should be generated based on the clinical judgment of the therapist. This list should not include any equipment that will not meet the client's needs, nor should it include equipment that is not needed. The therapist must be certain that the need for all components of equipment that are offered for trial can be justified. The therapist must determine the equipment that will meet the *needs* of the individual and select only from this subset of equipment for a trial. A trial in an ultralight manual wheelchair with a suspension shock system and off-road mountain bike tires for a user who requires friction-coated handrims and anti-tip devices is a misfit. Similarly, consideration of a power wheelchair with a large wheelbase and maximum torque settings for an individual who is expected to drive only indoors and on paved surfaces is inappropriate.

Equipment trials are very important and often not done due to time constraints or lack of access. Every attempt should be made to provide trials. If the trials are done after the stepwise assessment, there should be only a limited number of options. A client should have the opportunity to try different makes and models of equipment (from the subset of those appropriate for his or her

needs) and select the one that best meets his or her tastes or preferences.

It is imperative to do trials correctly. The trials must be a comparison of "apples to apples." Therefore, each wheelchair must be appropriately configured for the postural support needs and best push mechanics or drive mechanics of the individual, and all the wheelchairs used in the trial should be set up the same. The more specific the postural needs of the individual, the more important it will be to set up the wheelchairs in the *same* configuration so that a true comparison can be made. If the therapist simply does not have access to the specific equipment the client wishes to purchase, the therapist should attempt to simulate the features of the target equipment with the equipment that is available.

Trials should be guided by the therapist and therefore limited to the wheelchairs that meet the medical/postural and environmental/functional needs of the client. When there is no difference in the performance of the equipment, personal preference should be considered, as well as cost. When there is no difference in the cost of the equipment, considerations such as service record or time-to-delivery may be made. A particular make and model should be selected prior to measuring for the wheelchair. If equipment selection follows this careful algorithm, with documentation accompanying all decisions, then it will be easy to medically justify the final equipment (Fig. 8-8).

The properly prescribed and fitted seating system (wheelchair and interface) will support optimal posture and function. For the first seating system, this prescription should be completed with knowledge of the individual's potential function. There is no justification for compromise on the first wheelchair. The therapist is encouraged not to prescribe a more stable or less dynamic wheelchair just because it is a first wheelchair. Such a wheelchair will limit, and perhaps block, the acquisition of functional skills. Regardless of length of time since onset of SCI, manual wheelchair users should be provided with a wheelchair that may be customized to

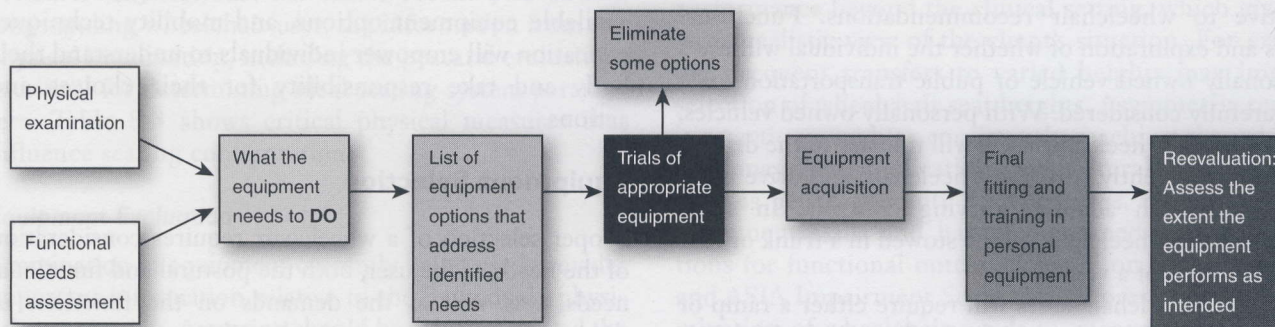


Figure 8-7. Flow diagram of clinical decision making in wheelchair prescription. Selection of equipment, wheelchair components, and configuration follows a systematic pathway. In each step, the therapist documents the requirements and the specifications required to meet these requirements.

Date:
 Patient:
 Physician:
 Therapist:
 Vendor:

Letter of Justification

To Whom It May Concern:

Client is a 63-year-old woman who has been a full-time manual wheelchair user since 1980 when she sustained a T9 incomplete SCI. Client has nonfunctional lower extremity motor control with some sensory sparing. She cannot ambulate for any distance; she cannot stand. She independently uses an ultralight manual wheelchair for all mobility when out of bed; she transfers to and from this wheelchair independently with a lateral lift transfer with full weight bearing on her upper extremity. Client complains of fatigue with excessive distance pushing and difficulty with stowing her current wheelchair into her car.

Client is currently using a manual wheelchair that is not appropriate for her postural or functional needs. Additionally, her current wheelchair is approximately eight years old making acquisition of parts impossible. The current equipment: Kuschall 3000 ST (rated K0005) manual wheelchair and a ~2-inch foam cushion (very compressed).

Client reports shoulder pain with stowing this wheelchair into her car (into passenger front seat of 2-door car). She also has difficulty with independent propulsion up steeper inclines and controlling steep descent. These difficulties are due to the weight of the current wheelchair and the lack of postural stability, which will be corrected by customized postural support incorporated into the frame parameters of a new wheelchair. Client is unable to functionally propel a lightweight or standard manual wheelchair due to the weight of the chairs and the limited positioning options.

Home environment: Primary residence is on rural 40 acres. Secondary (new) residence is a condominium in city—not an ADA accessible unit with some limitations in bathroom access. The primary residence is rural requiring daily transfers into the car to access any entertainment or essentials such as groceries.

With the current equipment, Client presents with the following postural problems: pelvic obliquity and frontal plane scoliosis, mild forward head and thoracic kyphosis, poorly controlled lower extremities. She reports some postural pain with prolonged sitting in the wheelchair. Client is 5'3" and ~135 pounds. She reports a history of multiple tendon releases secondary to significant spasticity and muscle shortening.

Client requires a new custom ultralight manual wheelchair. The specific equipment requested is a [*Name the exact make and model*] custom-specified titanium wheelchair with the following custom specifications:

- Custom-sized seat with tapering to accommodate the disparate hip to distal thigh width
- 14-inch seat depth to accommodate her short stature and lower extremity contractures

These features are not available in a K0004 chair.

- Custom backrest with tapering, rotation, and adjustable tension upholstery to accommodate disparate hip to back width and thoracic scoliosis
- This feature is not available in a K0004 chair.**

- Reinforced backrest rigidizer bar to support use as a handhold for physical assistance up and down stairs **for emergency egress from nonaccessible venues** (engineered to support body weight rather than just provide rigidity to back)
- Custom rear axle placement and frame parameters including seat to floor at front and rear and footrest drop angle to optimize postural support and provide for functional stability

4-inch difference front to rear with a 14-inch seat depth is not available on a K004 chair.

- Angle adjustable footplate to provide for accommodation of plantarflexion contractures and significant lower extremity spasticity
- Scissor wheel locks to provide safety for transfers while having no lock parts obstructing wheelchair propulsion or interfering with transfer providing skin safety for hands, posterior thigh, and buttocks
- Rigid side guards to augment the pelvic control by centering cushion and rider in the wheelchair

This wheelchair is significantly lighter than her current wheelchair (~30%); a lighter wheelchair will benefit Client in terms of maintaining the ability to independently stow the wheelchair into the car. Client has been a manual wheelchair user for more than 20 years and there is evidence to support an increase in shoulder pain and degeneration in spinal cord–injured persons greater than 15 years post-injury, therefore protecting the shoulder joint from biomechanical stress is a focus of preventative health care.

The dampening inherent in a titanium wheelchair should help decrease her current lower extremity spasticity especially the ankle clonus as well as decrease her low-back pain. If spasticity is a hyperactive stretch response; the innate reflexive contraction that is caused by a quick stretch to the muscle spindle is hyper-responsive due to the motor neuron condition created by the client's spinal cord injury at the level of T9. Spasticity is elevated by noxious stimulus anywhere in the body, thus a urinary tract infection or an ingrown toenail can elevate spasticity. Any physiologic pain, even if unperceived by the individual secondary to the interruption of spinal pathways, can elevate spasticity in an individual with an upper motor neuron syndrome. Titanium is a metal with natural shock-dampening characteristics, thus decreasing the stimulus to the muscle spindle and decreasing the expression of spasticity. The general increased ride comfort created by the characteristics of the material decrease stress to the body including weight-bearing seated surfaces and the lower back. The ultralight feature of the overall chair decreases the biomechanical stress of wheelchair propulsion. Any or all of the above can combine to decrease the expression of hypertonicity.

Her primary postural needs are for a custom wheelchair to fit her small stature and disparate hip-to-trunk measurements and scoliosis. Seat slope characteristics will accommodate hip flexion contractures while custom frame features will ensure lower extremity control and stability on inclines. Frontal plane corrections/accommodations are needed after sagittal plane is established and will likely be achieved through a modified cushion but will be augmented with the control from the custom backrest.

The patient has had successful trials in a wheelchair mocked up to meet most of the custom specifications.

I will be happy to answer any questions you have regarding this request. Thank you for your timely attention to this matter. I can be reached by phone at [*contact #*] or email: *wherever@some.com*

Sincerely,

Jennifer Hastings PT, PhD, NCS

Attachments: Wheelchair specifications, Drawings of specified wheelchair

Figure 8-8. Sample letter of justification. The letter details the specific requirement of the client to substantiate the need for the various components identified by the therapist.

the individual and that is constructed with high-strength, lightweight materials as supported by accepted clinical practice guidelines.⁶ In most cases, a rigid manual wheelchair is the appropriate selection for the SCI person who will independently propel the chair. The wheelchair should be custom configured to support posture through pelvic stabilization, which is built into the frame parameters and enhanced by the selected cushion and backrest interface. The options on the wheelchair should be selected based on functional needs as determined by lifestyle and abilities (current and potential). The power wheelchair system should likewise be optimized to provide the best possible postural support and the overground mobility necessary to meet the requirements of the individual's lifestyle with only the required power and seat functions. The clinical tendency in power is to overprescribe. The pressures of believing that there is "one shot" with third-party payers have led to too many functions being provided in a first wheelchair. The therapist should remember to prescribe based on needs, both postural and functional. When the individuals are "overstabilized" or "overprovided" with function, their potential for functional and neurological recovery is truncated. New equipment for the long-term user should never decrease function. The desired outcome is that the new equipment enhances abilities. In the delivery of new equipment, the individual should be assessed for just that. Functional skills should be checked out as a component of the final fitting. All habitual transfers should be evaluated; the ability to independently maneuver in a usual manner, including the use of wheelies and jumping curbs, etc., should be checked during delivery of the final system. Both vehicle access for power mobility systems and stowing the wheelchair into the vehicle for manual systems need to be specifically evaluated. It is likely that some fine-tuning of the setup may be needed to optimize posture and function.

Fitting and Education

Issue and Fit Process

Clearly, a significant investment of time, money, and brainpower is associated with determining the appropriate seating system for an individual with SCI. Perhaps the most important component in providing a seating system takes place when the final products are delivered to the client. The bottom line is that seating system products will not work optimally in the form in which they arrive from the manufacturer. It is the configuration, adjustment, and customized fitting to the individual that allows prescribed products to work for the client. The following is a proposed framework for fitting a seating system once prescribed products have been received:

- Review the products received: check measurements, orientation, and configuration to ensure that what was prescribed is what was actually received. The therapist should not settle for anything less than what was

ordered. An inaccurate dimension or configuration typically carries significant negative implications for the client and must be rectified prior to scheduling the client for equipment fitting.

- Arrange for the complete seating system to be assembled and operational before the client arrives for the fitting and adjustment process.
- Get in the wheelchair and push it or drive it to rule out any problems (such as tracking or instability issues) before the client arrives.
- Following general assembly, adjustments and a fine-tuned fit to the individual make all the difference in the world. A general guideline for a sequence of adjustments once the client has been positioned in the seating system follows:
 1. Check basic fit, with cushion, backrest, and accessories in place.
 2. Adjust the backrest angle.
 3. Adjust backrest height.
 4. Adjust footrest height.
 5. Adjust accessory supports.
 6. Adjust rear wheel position (manual wheelchair skills).
 7. Set up the drive control; install switches, and program parameters to maximize control in all settings (power wheelchairs).
 8. Check wheelchair skills and maneuverability in varied environments and terrain.
 9. Further adjust seating system as needed.
 10. Perform pressure mapping and skin inspection to identify concerns.
 11. Further adjust seating system as needed.
 12. Provide comprehensive education.

Client Education

Throughout the process of evaluation and provision of seating system interventions, client education must be an integrated theme. The amount, extent, and content of the actual education provided varies depending on the length of time the individual has been a wheelchair user, the strength of his or her preferences, and the willingness to consider new concepts and technology.

With the issuance of definitive seating system equipment, the following education topics should be addressed with the client.

- Review of proper seating system configuration (e.g., cushion orientation)
- Basic equipment operation and safety
- Maintenance recommendations
- Push mechanics (manual) or driving strategies (power) for efficiency and injury prevention
- Review of transfers to and from the wheelchair to varied surfaces
- Recommendations for pressure relief and skin protection
- Stow techniques into a vehicle (manual) or driving strategies to access a van or public transportation (manual or power)

In addition to education specific to equipment management and mobility, several topics should be addressed with all wheelchair users. Activity of daily living (ADL) techniques must be emphasized to minimize the risk of upper extremity injury while performing functions from a wheelchair. Fitness, weight management, and general wellness strategies should be encouraged to promote lifelong health. Appropriate stretching, strengthening, and conditioning exercises can be prescribed to encourage optimal function while preventing injury. It is typically appropriate to stretch the anterior chest and shoulder musculature and strengthen the posterior shoulder, trunk, and intrascapular muscles as needed, depending on the client's presentation. Comprehensive client education empowers individuals to take responsibility for their own body, to make informed decisions, and to live a healthy and balanced life despite reliance on a wheelchair for mobility.

Outcomes

Seating interventions must be documented with outcome measures. Objective goals for the seating system will help determine the appropriate outcome measure. If the goal is to improve functional endurance with a lighter wheelchair that has less roll resistance, then the therapist should document the current ability. Timing the ability to maneuver an obstacle course or a 6-minute push test (the wheeled mobility equivalent of the 6-minute walk test) are appropriate assessments. Include a perceived exertion score¹⁰³ after completing the mobility test. Vital signs may also be helpful for documenting the heart rate or respiratory rate after propulsion in persons with SCI below T6.

Document the same measure in the ultralight wheelchair. If the therapist can do this during trials, the information provides the evidence to support the letter of justification. The therapist must be sure to document these measures as an outcome in the definitive equipment chosen.

First wheelchairs are prescribed based on the evidence in the literature. For instance, the current evidence supports the fact that the individual with SCI is best served in an ultralight manual wheelchair made from high-strength, lightweight material with customized configuration for optimal posture and push mechanics.⁶ New equipment for seating, whether it be a complete system, a mobility base, or an interface component (backrest or cushion), must also have goals and outcome measures.

If the goal of the intervention is postural support, then the therapist should objectively document current posture. Photographs and anatomical measures such as rib-to-iliac clearance, sternal angle off vertical, and seated height are recommended for preintervention and postintervention documentation. These measures will show that posture was indeed changed with the new seating configuration.

Whether or not the postural change matters to the individual is best documented with a subjective or patient-reported outcome scale. The Posture Scale for Wheelchair Users was developed to assess the wheelchair users perception of seated posture (see Appendix). In a pilot study, this measure showed good face validity, concurrent validity, and good internal consistency (reliability).¹⁰⁴

If the client's complaint was musculoskeletal pain and the postural intervention was directed at the postural contribution to mechanical pain, then the therapist will want to use a measure such as the Wheelchair User's Shoulder Pain Index^{105,106} to document change in pain.

If the seating intervention was directed at skin issues, the therapist will need objective measures such as pressure mapping, as well as frequency, severity, and location of skin concerns. These measures should be documented preintervention and postintervention.

Functional ability in a wheelchair can be affected by seating. If the seating intervention is directed at functional improvement, an outcome measure of function may be appropriate. One such measure is the Functioning Evaluation in a Wheelchair (FEW) measure.¹⁰⁷ Additional outcome measures specific to wheelchair skills are the Wheelchair Circuit^{108,109} and the Wheelchair Skills Test.^{110,111}

Seating for SCI as Lifelong Disability

One of the goals of early proper postural support through appropriate seating prescription is to avoid negative sequelae. Many of the common secondary complications associated with SCI are preventable, and proper postural support is critical to prevention.

However, even with the best initial prescription based on the thorough postural and functional evaluation delineated earlier in this chapter, it is necessary to monitor posture and seating throughout the client's lifetime. The reasons are many. One aspect is the growing knowledge of rehabilitation science and evolving technology in equipment. With time, rehabilitation science pertaining to seating is getting better. We have increased our knowledge of postural interaction with the upper limb mechanics, and we will continue to investigate postural interactions with other health outcomes. Equipment will continue to evolve, offering more possibilities with design features and perhaps more advantages in new materials. Another reason is that people are dynamic. They are not static in their life interests, social roles, or functional needs. These changes may therefore change the requirements of their equipment. Physically, people are not static either. With aging, all people will change physiologically. There is a change in tissue structure with aging. Bones tend to decrease in density, muscles tend to atrophy, fat distribution changes, and skin loses its elasticity. With SCI, all of these changes continue to occur and some at an accelerated pace.¹¹² There are physiologic

changes in organ function with aging as well. Generally, there is a decrease in systematic circulation, loss of vital capacity in lung function, and a slowing of gastrointestinal and urologic functions. Again, all of these changes occur with SCI as well, and most at an accelerated rate.

For seating, these changes may be reflected most in the requirements for skin protection. The loss of muscle tissue and subcutaneous fat combined with a decrease in skin elasticity and decreased circulation increases the risk of skin breakdown. The physiologic changes with aging often drive functional and lifestyle changes in the general population, and this is no different for individuals with SCI. Again, this may occur at a more rapid rate, and thus the functional needs and the abilities must be frequently monitored to determine whether they indicate a change in equipment. Unfortunately, not every individual with SCI was afforded the best postural support early after injury and therefore may have acquired postural deformities that need to be corrected (if possible) or accommodated through seating prescription. Because many of these deformities have developed progressively over years, it is common that individuals slowly and progressively accommodate their functional techniques to their physical capacities. It is imperative that a seating therapist who is evaluating an individual with long-standing SCI be very careful and thorough in the evaluation of the functional strategies and how the current equipment interfaces with the individual's functional movement strategies. Habits are hard to break, and function is a very strong motivator. The therapist evaluates function as a component of seating intervention to ensure that the chair supports function and the particular movement habits that work best for the individual. The intervention may be needed for skin health or postural alignment, but if function is lost, it will not be successful (and if the individual has the option they will discard the new system). Pain is the only motivator stronger than function, so unless the individual has pain that goes away after a seating intervention, the intervention will be declined if function is threatened.

Some examples of well-intended but failed interventions:

Prescription: A new ultralight titanium folding manual wheelchair to an individual with paraplegia who is 20 years post-injury.

Goals: Increased mobility with better push mechanics in lighter adjustable equipment

Justification: Shoulder pain and aging.

Reason for Failure:

1. The transfer technique was to put the feet up on the surface being transferred to; the new wheelchair would tip rearward with this activity.
2. The wheelchair stow habit was behind the front passenger seat. The new wheelchair did not fold to be narrow enough and required the rear wheels to be removed.

In this example both of the functional habits had the potential to be changed in order to successfully use the new wheelchair. The client should have been evaluated for the potential for, and interest in, learning new techniques for both transfer and wheelchair stowing. It is important to remember that functional techniques often evolve out of progressive physical impairments. In this case, the individual had significantly overstretched hamstrings, resulting in loss of ability to perform short-sitting without a backrest. Changing his transfer technique was not a viable option. If wheelchair stowing had been evaluated, then the client would have been very clear that he was not open to removing the rear wheels nor acquiring a new vehicle.

Marginal function should be considered sacred. Some individuals can just barely move, but most relish this movement. Some individuals have adopted sitting postures that allow this limited mobility, and it works for them in their movement strategies. The therapist must be very wary of taking this away.

An individual with C6 tetraplegia who is a manual wheelchair user for 25 years. Posture is kyphotic with posterior pelvic tilt. He has had skin breakdown, which is now healed. The individual uses a 2-inch open cell foam cushion with nylon upholstery. Referral is for a new cushion with increased skin protection and postural correction.

Prescription: Hybrid technology cushion with an anterior wedged base and an immersion overlay.

Goals: Increased postural support to decrease posterior tilt with the anterior wedge feature and improved skin protection with pressure distribution via immersion.

Justification: History of recent skin breakdown with postural deviation.

Reason for Failure:

1. Postural correction interferes with function. This individual's ability to transfer depends on his ability to move forward in the seat, which is lost on the contoured base; additionally, the immersion surface is less stable and decreases his ability to move.
2. The increased skin protection is gained by the immersion feature of the cushion but this feature decreases this individual's function. Due to the instability, his transfer and his pressure relief method are lost.

Negotiated Solution: the same thing he has been successfully using (open cell foam with nylon cover) but new and one inch thicker with replacement at six months.

Table 8-4 provides examples of typical postural presentations that can occur in individuals with long-standing SCI. The postural deviation is defined, and potential causes of the deviations are given, along with recommended seating interventions for each deviation.

Table 8-4
Common Postural Deviations in Individuals with SCI

Typical Presentation	Postural Deviation	Potential Causes	Recommended Seating Interventions
<p><i>Forward head position:</i> Collapsing forward, propping with upper extremities Anterior thoracic fold at base of sternum Lumbar flexion Increased thoracic kyphosis Scapular protraction with humeral head forward in glenoid fossa High cervical hyperextension <i>Skin:</i> Bilateral ischial skin breakdown, perineal skin breakdown, may present with sacrum and coccyx pressure, and at spinous process at apex of thoracic kyphotic curve. May have anterior moisture breakdown in skin folds <i>Pain:</i> May complain of head ache, upper back pain, discomfort with prolonged sitting in wheelchair, shoulder pain with propulsion</p>	<p><i>Posterior pelvic tilt:</i> Pelvis is rotated backward from neutral sagittal plane alignment</p>	<p><i>Anatomical:</i> Limited hamstring length Fixed kyphosis Limited lumbar extension Anterior chest tightness <i>Equipment:</i> Seat depth too long Lack of posterior pelvic and lumbar support Backrest reclined Backrest too high Footrests too low</p>	<p><i>Flexible spine:</i> Provide support for neutral pelvic position and lumbar extension. Likely corrections are seat slope, backrest angle and backrest height (or backrest contours where height is required) <i>Inflexible spine:</i> Address seating system configuration to accommodate posterior pelvic position and resultant kyphosis. Rotate system in space to provide horizontal line of sight and prevent musculoskeletal pain. Provide support to prevent progression of deformity. <i>Education:</i> As appropriate, stretching for hamstrings, thoracic extension, anterior chest and shoulder muscles. Strengthening posterior shoulder and intrascapular muscles. Stretch for posterior neck muscles and sternocleidomastoid.</p>
<p>Asymmetrical shoulders—Shoulder elevated same side as low pelvis Neck musculature shortening same side as low pelvis Asymmetrical stomach with abdominal bulge laterally same side as low pelvis Asymmetrical pelvis Spinal scoliosis with rotation Pelvic rotation may exist.</p>	<p><i>Pelvic obliquity</i> One side of the pelvis is lower, creating frontal plane asymmetry. Compensatory curve away from low side.</p>	<p><i>Anatomical:</i> Limited hip flexion contralateral to obliquity Unilateral hip flexion contracture Asymmetric spinal fusion Asymmetric lateral abdominal or hip flexor spasticity contralateral to obliquity Asymmetric flexibility due to habitual function: reach to one side, rotate to one side for access, one side only transfers</p>	<p><i>Flexible spine:</i> Provide support to lift low side of pelvis; provide associated trunk support if needed <i>Limited hip range:</i> Accommodate to allow neutral pelvis <i>Inflexible spine:</i> Accommodate and provide support at pelvis at high side to increase pressure distribution and support trunk to prevent progression of deformity.</p>

Continued

Table 8-4
Common Postural Deviations in Individuals with SCI—cont'd

Typical Presentation	Postural Deviation	Potential Causes	Recommended Seating Interventions
<p><i>Skin:</i> Breakdown at the ischial tuberosity, greater trochanter or posterior-lateral ribs on same side as low pelvis</p> <p><i>Pain:</i> Cervical pain on same side as low pelvis; may present with shoulder pain either side</p>		<p>Head righting, seeking a head vertical; eyes horizontal and forward line of sight will exacerbate compensatory deformity created by an asymmetric pelvic platform</p> <p><i>Equipment:</i> Trunk shift due to lack of adequate support or equipment that is too wide.</p> <p>Joystick drive control with lateral placement</p>	<p><i>Education:</i> Stretching for lateral trunk and neck musculature. Avoid repetitive functional activities that elongate or shorten in the pattern of the deformity</p>
<p>Arching over the top of the backrest Excessive lumbar lordosis May sit with pelvis forward to reverse curve Flat thorax Unstable sitting balance. Pelvis sits posterior on cushion with ischii at most posterior aspect of cushion</p> <p><i>Skin:</i> Issues at perineum or coccygeal breakdown (from backrest or bed surface)</p> <p><i>Pain:</i> Upper back and neck pain, may present with upper limb pain</p>	<p><i>Hyper-anterior pelvic tilt:</i> Pelvis is rotated forward from neutral sagittal plane alignment</p>	<p><i>Anatomical:</i> Hip flexion contractures Spinal fusion in extension Premorbid lumbar hyperextension Hypermobility lordosis below spinal fusion</p> <p><i>Equipment:</i> Horizontal seat plane in the presence of truncal paralysis and hip flexion contractures</p> <p>Overstretched backrest upholstery Inadequate backrest support Backrest too low</p>	<p><i>Flexible spine:</i> Configure seating system to facilitate neutral pelvic and trunk alignment. This requires a significantly steep slope or a combination of seat slope and cushion contour to decrease pull of the hip flexor contractures on the lumbar spine.</p> <p><i>Inflexible spine:</i> Ensure appropriate cushion support under pelvis. Adjust back support for lumbar extension. Rotate the system in space to provide horizontal line of sight. Configure for stability. Configure seating system to prevent progression of deformity.</p> <p><i>Education:</i> Stretching for hip flexors and spinal extensors.</p>
<p>Asymmetrical lap Trunk rotation Uneven pelvis One knee forward of the other, creating transverse plane asymmetry</p>	<p>Upper leg length discrepancy (LLD) Short limb internally rotated</p>	<p><i>Anatomical:</i> A true pre-SCI leg length discrepancy Subluxed or dislocated hip on short side History of femur fracture with resultant shortening</p>	<p><i>Flexible:</i> (i.e. pelvic rotation) Provide support and stabilization to neutralize pelvic position.</p>

Table 8-4
Common Postural Deviations in Individuals with SCI—cont'd

Typical Presentation	Postural Deviation	Potential Causes	Recommended Seating Interventions
		<p><i>Equipment:</i></p> <p>If equipment angles or dimensions do not accommodate anatomical limitations, the equipment will create or increase deformity</p>	<p><i>Fixed:</i></p> <p>Provide seat depth and cushion modifications to accommodate LLD. Accommodate fixed pelvic and trunk positions.</p> <p><i>Education:</i></p> <p>With fixed LLD, allow asymmetric lower extremity (LE) alignment vs. attempting to correct with pelvic rotation.</p> <p>Educate about the interaction of the pelvis with spine and the curvature with rotation need to compromise LE positioning to preserve upper body alignment and biomechanics</p>
<p>Windswept posture</p> <p>One upper leg abducted with external rotation while opposite leg is adducted with internal rotation</p> <p>May present with skin issues at feet, knees, or greater trochanter</p>	<p>Pelvic rotation</p> <p>Pelvic obliquity</p> <p>Scoliosis</p> <p>Unilateral cervical contracture</p>	<p><i>Anatomical:</i></p> <p>Pelvic rotation</p> <p>Trunk rotation</p> <p>Unilateral or asymmetric hip adductor spasticity</p> <p>Limited hip flexion (adducted leg)</p> <p>Limited hip abduction (adducted leg)</p> <p>Limited hip adduction (adducted leg)</p> <p><i>Equipment:</i></p> <p>If equipment angles or dimensions do not accommodate anatomical limitations, the equipment will create or increase deformity.</p>	<p><i>Flexible:</i></p> <p>Provide support for pelvis, trunk, and lower extremities to position at neutral alignment</p> <p><i>Fixed:</i></p> <p>Accommodate with cushion and backrest modifications. Provide supports to prevent progression of deformity.</p> <p><i>Education:</i></p> <p>LE, trunk, and cervical stretching.</p>

When SCI Occurs in the Young

There is considerable literature to support the belief that postural deformities are more prevalent in persons for whom SCI occurred as a child.^{35,113} There are high rates of dislocated hips and scoliosis, and many children with SCI are prescribed long-term spinal orthoses use or have

surgical stabilization against progressive spinal deformity. It is hypothesized that the immature skeletal system plays a part in the development of these deformities. These concepts will be explored in greater detail in Chapter 25.

If a paralyzed trunk is unsupported, then it will align to a position of stability, which is spinal flexion. If a pelvis is

not contained with medial and lateral support, then it may shift to one side, setting up a pattern of scoliosis from lack of a stable platform. A seating system that is too large is *much* more dangerous than one that is too small when the outcome of concern is postural alignment. Too often, children are seated in equipment that is too large. Even if the seat itself has been properly downsized to fit the child, the wheelchair base is often heavy and cumbersome. What is known from the body of research on upper limb musculoskeletal pain in individuals with SCI is that posture and proper upper limb biomechanics are essential. Furthermore, wheelchair roll resistance should be minimized through engineering to protect the individual who will push a wheelchair for full-time mobility. The person who suffers SCI earlier in life is the *most* in need of this protection, as they have the longest life remaining. As soon as a child is mature enough to safely maneuver his or her own equipment the child should be granted all of the same considerations discussed throughout this chapter. Nearly all of the high-end ultralight wheelchair manufacturers have some version of a trade up or discounted rate to rebuild for growth. Nearly all of the power mobility manufacturers have seating components that can grow over the mobility base. It is imperative that seating professionals do the best possible job of prescribing seating systems for children with SCI and of advocating for the best available equipment.

Wheelchairs for Sport and Recreation

Wheelchairs designed for sports and recreation are often used by individuals with SCI. While it is beyond the scope of this chapter to discuss in detail the appropriate

prescription of wheelchairs for various adaptive sports and recreation activities, we will outline some important considerations.

- It is imperative that the same issues be addressed as those for everyday seating systems: postural support, skin protection, comfort, and function.
- A clear understanding of the client's interests, experience, goals for the specific equipment, intentions for use (whether recreational or competitive), and available support for pursuing a sports or recreational goal is necessary for appropriate prescription.
- Sports wheelchairs vary greatly; therefore, a thorough understanding of the sport activity is necessary for appropriate wheelchair prescription. In a team sport, it is important to consider the position played.
- The experience and skill level of the athlete also guides equipment decisions.

Sports wheelchair prescription requires a number of specific considerations in order to prescribe an appropriate athletic device. Therapists who lack competence in prescribing sports and recreation equipment are encouraged to seek guidance and mentorship from colleagues with this specific skill set.

Case Studies

The following two cases illustrate key concepts related to the wheelchair prescription that have been discussed in this chapter.

CASE STUDY 8-1 Individual with C5 Tetraplegia Seated in a Power Wheelchair

The client is a 22-year-old woman with C5 tetraplegia with partial motor preservation in C6 on the right, who is seen in an outpatient seating clinic. She breathes independently and uses a joystick-controlled power wheelchair. A car accident 4 years ago resulted in SCI. The client lives at home with her parents and attends community college. She hopes to transfer to an out-of-state university next fall. For school, she uses a note taker in class and a dictation system at home. The family owns a ramped minivan in which she travels as a passenger while seated in her power wheelchair. She does not drive and has no intention to return to driving.

Client is 5 foot 5 inches tall, with a reported weight of 125 prior to SCI. She believes she now weighs approximately 135. She reports she is in a wheelchair from about 8 a.m. to 10 p.m. She reports she does not use the elevating leg rests and cannot use them independently. The client states she does not use the tilt for pressure relief but she does use it once a day, as a rest position.

Client reports she has had no skin health issues. Her mother reports one area in high sacrum that gets red.

Key Concerns

1. Client: "It feels like I am tipping more forward since my injury, and through the day, my neck is pulling me down. I also tip to the left. It does not seem like spasms." Client also does not like the fact that her legs are spread apart.
2. Mother: She is concerned that her daughter is leaning over to the left, developing scoliosis that seems to be worsening.
3. Regular PT states: The wheelchair is contributing to the kyphosis and rounded shoulder and poor lateral control.

The interview will help determine the functions this client requires in a wheelchair. From what is already known, a list of the functions of her wheelchair can be created.

For mobility:

- Must provide all-day mobility
- Must provide for 12 to 14 hours of battery life in community mobility
- Must be able to access family minivan

CASE STUDY 8-1 Individual with C5 Tetraplegia Seated in a Power Wheelchair—cont'd**Platform for function:**

- Must provide all day sitting position
- Must provide pressure relief
- Must provide positional change for functional tasks
- Must provide comfort
- Must provide postural stability

Considering this list, the therapist determines whether the current power base and interface equipment is appropriate.

Current System Information

Make/model of wheelchair/base: Permobil Chairman tilt in space with elevating leg rests and elevator (a FWD power base, with rehab seating and power functions).

Make/model of backrest: Jay 2 Deep Contour (adult large, 18-inch shell height) backrest is bolted on to backrest (a contoured backrest with lateral contours). Pan not mounted with hardware.

Make/model of cushion: High Profile Roho 10 × 9 (an air-filled cushion).

A review of the client's needs and the characteristics of the power base and seating interface reveal that the equipment is appropriate. The Permobil is a high-end power base with adequate range and ground clearance for community mobility. The power tilt offers pressure relief ability and the elevator allows ease of dependent function as well as positional changes required for varied tasks. The fact that the elevating leg rests are not under power control and not used means that they are likely an unnecessary component. Physical examination results will determine whether they are also potentially detrimental to postural support. The Jay 2 Deep Contour backrest also appears to have the potential to meet the needs of this client; the size may be an issue due to the small stature of the client. The high-profile Roho cushion is at the high end of skin protection, but may provide less-than-needed postural stability.

Physical Examination

Client and range of motion measurements are as follows:

PROM:	Left	Right
Hip flexion without post pelvic tilt	100	100
Hip extension without anterior pelvic tilt	-25	-15
Knee extension with hip at 90 (inside <)	135	135
Rule out hip limitations (abduction/adduction, or rotation)		
Problem? No		
Thigh length (mat to popliteal)	15.5	15.5
Dorsiflexion ROM	20	20
Foot/ankle deformity? No		
Upper extremity deficits? Yes		

Scapulae bilaterally are excessively elevated with inferior angle approximation. Limited extension on the right glenohumeral joint. Right upper extremity is stronger than left

Current equipment measures and angles are as follows:

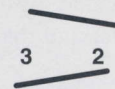
- Seat depth: 18 inches
- Seat width: 17 inches
- Backrest height: 24 inches
- Footrest length: 15 inches
- Front seat-to-floor height: 20 inches
- Rear seat-to-floor height: 18.5 inches
- Inside angle seat to backrest: 100 degrees
- Seat to footrest angle: 95 degrees

Postural Evaluation

(Schematic representation of the shoulder and pelvis by lines; rib-to-iliac space indicated in number of fingers.)

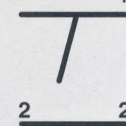
Short-sitting evaluation:

(Fig. 8-9 illustrates initial seated posture)



Some rotation of the pelvis, transverse plane

Supine: (hip flexor tightness with hyperlordosis)



The physical examination will help the therapist determine the postural needs.

Postural Issues

Truncal paralysis suggests a need for orthotic support in the sagittal plane

Client is wider at hips than the back, which suggests she may need narrower backrest to fit appropriately

Significant hamstring and hip flexor contractures require accommodation with seat slope via frame configuration or interface

Sits with scoliosis with a rotatory deformity; however, this may be partially functional, as she can straighten in supine. It may also be partially due to oversized equipment providing less-than-adequate support

Reviewing the findings will give the therapist a general impression and some hypotheses as to the problems in the configuration of the current equipment.

Impression:

- Seat depth is too long (it is longer than her thigh measurement).
- Backrest is too high (laterals impinging on axilla).
- Reclined backrest is facilitating posterior pelvic tilt.
- Leg control is poor with down-sloped thighs and abduction.
- There is apparent pelvic obliquity with right side low—the pelvic obliquity appears to be a somewhat flexible deformity as lifting appeared to improve alignment and aid stability.

Continued

CASE STUDY 8-1 Individual with C5 Tetraplegia Seated in a Power Wheelchair—cont'd

The most critical component of successful seating is for the equipment to *fit* the individual. Equipment that is *too large* is detrimental to posture, especially in the condition of truncal paralysis. Because the client's seat depth measures 2.5 inches *longer* than her thigh length, she absolutely cannot sit without a significant posterior pelvic tilt. Until this is neutralized, it is not possible to have a true assessment of the rest of her postural deformity. Because her pelvis is being pulled forward by the lower leg, the asymmetrical hip flexion contracture may explain the postural deviations above the pelvis.

At this point, empirical trials are required to determine the affect of a shorter seat depth. The sagittal plane orthotic support can be created using a base wedge (or the tilt function) to create a positive seat slope, decreasing the seat-to-backrest angle, and lowering the backrest. Because the backrest is mounted without the adjustable hardware, the initial position will need to be more reclined than ideal, and the lower backrest will not allow

optimal pelvic positioning (Fig. 8-10 illustrates interim seated posture).

The adjustment of the current equipment is sufficient to verify that these changes are on the right track. To finalize the changes, it will be necessary to order different equipment, in particular a kit to shorten the seat depth and a tubular backrest to allow optimal mounting of aftermarket backrests with appropriate angle adjustment.

With final equipment, the seating is significantly improved (Fig. 8-11 illustrates final seated posture). This case primarily illustrated a change in configuration of the equipment. The power base and the interface equipment remained the same. The size and configuration of the equipment changed. The seat depth was shortened, the seat-to-backrest angle was closed (but the top of the backrest reclined), and a positive seat slope was added.

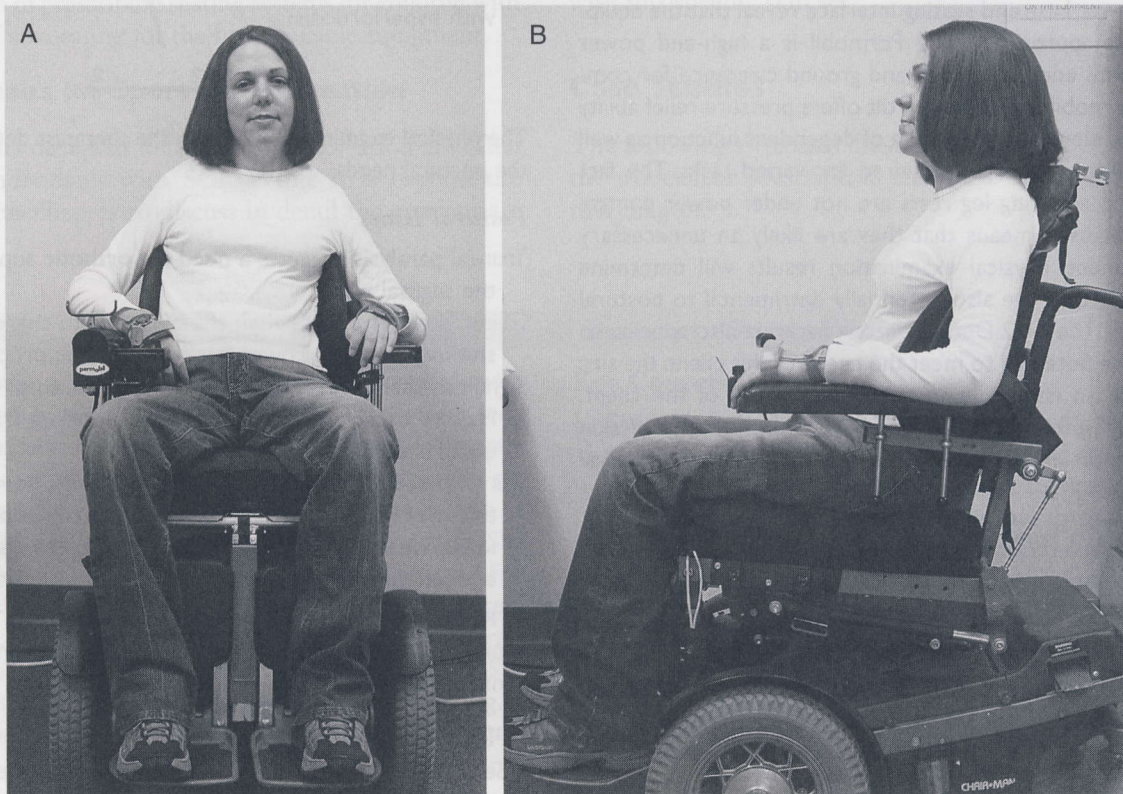


Figure 8-9. Initial posture of subject in Case Study 8-1. (A) Frontal view. Note apparent pelvic obliquity and abduction/external rotation of the hips. (B) Sagittal view. Note reclined backrest, posterior tilt of the pelvis, and downslumped thighs.

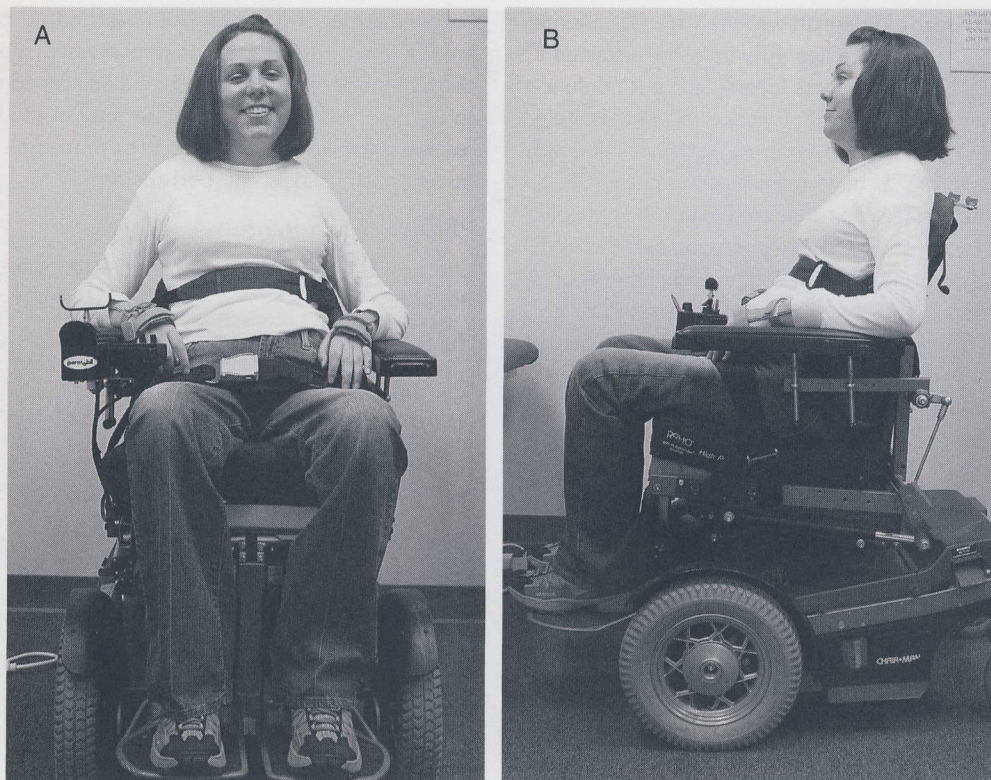
CASE STUDY 8-1 Individual with C5 Tetraplegia Seated in a Power Wheelchair—cont'd

Figure 8-10. Interim posture of subject in Case Study 8-1 with original equipment. While some desired adjustments were not possible with the original equipment, reconfiguration resulted in improved postural positioning. (A) Frontal view. Note improved positioning of the legs. (B) Sagittal view. Note improved thigh-trunk angle created using the tilt function on the wheelchair, decreasing the seat-to-backrest angle and lowering the backrest.



Figure 8-11. Post-intervention posture of subject in Case Study 8-1 with new equipment. (A) Frontal view. Note improved alignment of the trunk and pelvis that places even the shoulders in a more natural position. (B) Sagittal view. Note more optimal position of legs and trunk with shorter seat depth and positive seat slope.

CASE STUDY 8-2 Individual with T9 Paraplegia Seated in a Manual Wheelchair

The client is a 63-year-old woman who has been a full-time manual wheelchair user since age 40 when she sustained a T9 incomplete SCI. Client reports incomplete, but nonfunctional, lower extremity motor function. Client is self-referred for seating evaluation in an outpatient clinic with the goal of acquiring a new manual wheelchair. Client reports her current wheelchair is approximately 8 years old.

Client reports that she has some postural problems with some associated pain in upper back and neck. She reports shoulder pain, especially with stowing wheelchair into car (into passenger front seat of two-door car).

Client reports no history of skin problems. She reports low lumbar scoliosis without correction and a history of releases in hip flexors, knees (hamstring), and adductor tendons approximately 18 years ago. Client reports lower extremity spasticity, especially into plantarflexion. Client is 5 feet 3 inches tall and weighs approximately 135 pounds.

Client reports some wheelie skills, but no curbs and few sidewalks in her environment.

Client reports dressing in the wheelchair as well as self-catheterization.

Client is independent in lateral transfers to level surfaces with marginal skills. She requires a firmly locked wheelchair. She reports she does not often transfer out of the wheelchair except to bed.

The client's primary residence is on a rural island property of 40 acres. She has a secondary (new) residence in a condominium in urban locality. The unit offers limited accessibility to the wheelchair including some limitations in bathroom access (requires turning radius limited to that of current wheelchair).

Her husband will assist up steeper inclines and down steeper descents for control. Additionally, client has local family with stairs to access the home; husband pulls her up backward in the wheelchair, which requires a push handle assembly. Client requests a removable push handle system.

Key Concerns

1. Client is hoping for the lightest wheelchair possible to maintain her independence.

The information from the interview will assist the therapist in determining the functions the client requires in a new wheelchair. From what is known, a list of the functions of her wheelchair can be created.

For Mobility

- Must cover rough terrain with limited skills
- Must be set up for dependent assist
- Must be lightweight (for stow and removal from car)
- Must provide all-day sitting position

Platform for function

- Requires rearward stability (for dressing in wheelchair)
- Requires adequate seat/frame depth (for self-catheterization)
- Requires stable platform for transfers
- Requires compact wheelchair for accessibility

Summarizing what has been learned, it is possible to predict what wheelchair components are appropriate. The client's mobility habits and skills and her environment suggest an ultralight manual wheelchair set up for good forward and rearward stability, with treaded tires, moderate-sized soft roll casters, push handles, and, perhaps, armrests.

Physical Examination

Client and range of motion measurements are as follows:

PROM:	Left	Right
Hip flexion:	120	130
Hip Extension	-30	-35
Hamstring length (inside angle with hip at 90)	120	130
DF	-5	-10
Thigh length	15 inches	15 inches

LE contractures with firm end feels

Trunk with some flexibility but limited in lateral flexion to left

Current equipment measures and angles are as follows:

Kuschall 3000 ST (an ultralight cantilever frame wheelchair) and an ~2-inch foam cushion (very compressed)

Seat depth: 16 inches

Seat width: 16.5 inches

Backrest height: 16 inches

Footrest length: 16.5 inches

Front seat-to-floor: 19.25 inches

Rear seat-to-floor: 16 inches

Inside seat-to-backrest angle: 90 degrees

Seat to footrest angle: 80 degrees

Inside footrest: 11 inches

Camber: ~3 degrees

Wheel clearance: .75 inch

Center of gravity (measure of rear axle forward of rear frame): 2.5 inches

Rear frame to caster tube: 15 inches

Overall width: 25.5 inches

Overall length (including toes): 33 inches

Postural Evaluation



Short-sitting evaluation findings are as follows (Fig. 8-12 illustrates initial seated posture):

- Left pelvis is low, right shoulder is low
- Right hip is externally rotated and slightly abducted
- Left hip is slightly internally rotated and adducted
- Sagittal plane appears highly unstable to the rear
- Down-sloped thighs
- Posterior pelvic tilt
- Mild forward head
- Thoracic kyphosis

CASE STUDY 8-2 Individual with T9 Paraplegia Seated in a Manual Wheelchair—cont'd



Figure 8-12. Initial posture of subject in Case Study 8-2. (A) Frontal view. Note curvature of trunk and rotation of pelvis. (B) Sagittal view. Note reclined position of backrest imposes forward head posture.

The physical examination will help the therapist determine the postural needs.

Postural Issues

Truncal paralysis requires orthotic support in sagittal plane. Scoliosis with rotatory deformity, which suggests some accommodation for appropriate contour and support. Significant hamstring and hip flexor contractures (requires accommodation in frame configuration).

Reviewing the findings of the physical examination and the measurements of the current equipment will give the therapist a general impression of problems with the current equipment and indications of the best directions for configuration of the new equipment.

Impression:

Her postural support needs suggest a wheelchair that can be highly customized.

Frame features will include

- a fairly steep seat slope with the front of seat higher than the rear of seat at approximately 14 degrees above horizontal. This feature will accommodate her hip flexion contractures and provide orthotic sagittal plane support.

- a tight front frame drop angle (approaching vertical); this feature will accommodate the hamstring contractures.

However, this configuration can be quite unstable and she requires stability, therefore

- caster position should be forward with the foot support between the casters.
- axle position can be adjusted to improve rearward stability
- the backrest angle will be either vertical or forward of vertical.
- inside seat-to-backrest angle will be acute (<90).
- her frontal plane asymmetry may require correction, but this will be evaluated after sagittal plane correction with proper wheelchair frame configuration.
- rotatory deformity is a fixed deformity and must be accommodated with asymmetry built into backrest.

At this point, some configuration changes to her existing equipment are warranted in order to prepare the client for the recommended changes that will be incorporated in new equipment. Trials in appropriate wheelchairs should be arranged.

The final selection for this client was a custom titanium rigid wheelchair with the following frame parameters:

Continued

CASE STUDY 8-2 Individual with T9 Paraplegia Seated in a Manual Wheelchair—cont'd

Front STF: 19 inches
 Rear STF: 15 inches
 Seat depth: 14 inches
 Footrest: 14 inches
 Width: 16 inches rear, 14 inches front
 Inside seat-to-backrest angle (right cane 2 degrees forward of left): 75 inches
 Backrest height: 14 inches
 Inside footrest: 10 inches
 Footrest angle: 80 (to floor)
 Camber: 4 degrees
 Wheel clearance: .75 inches
 Center of gravity: 3 inches
 Rear frame to caster tube: 17 inches
 Overall width: 25 inches
 Overall length: 31.5 inches

Note the following changes to the wheelchair configuration:

- A shorter seat depth and footrest length: These measures now match her anatomy. (Fig. 8-13 illustrates final seated posture.)

- A steeper seat slope, shorter backrest, and more acute seat-to-backrest inside angle: These features accommodate hip flexion contractures and provide sagittal plane orthotic support to spinal alignment.
- Shorter seat depth and decreased footrest drop angle: These features accommodate her hamstring contractures.
- Longer frame measure between the rear frame and caster housing: This feature improves the stability of the wheelchair.

A letter of justification to the third-party payer (Refer to Fig. 8-8 for sample letter) was written to facilitate acquisition of this wheelchair. The therapist justified the need for the wheelchair in general, the need for the category of wheelchair being requested, and the need for each specific specialized component, which will include charges for customization as well as any equipment beyond standard.



Figure 8-13. Post-intervention posture of subject in Case Study 8-2 with new equipment. (A) Frontal view. Note improved trunk, pelvis, and leg alignment. (B) Sagittal view. Note more acute seat-to-backrest angle to accommodate hip flexion contractures and decreased footrest angle to accommodate hamstring contractures.

Summary

The ideal seating system for the individual with SCI maximizes mobility and activity, minimizes injury risk, is comfortable, and provides an optimal platform for both physical and physiologic function. Optimal seating outcomes are the result of a comprehensive client evaluation, equipment trials with appropriate products, and provision of a final system that matches the unique needs and preferences of the individual. A thorough client evaluation includes assessment of physical, functional and social needs. Once the client's requirements are identified, the broad field of equipment choices may be narrowed to coordinate appropriate trials with products that are likely to meet specific objectives. Seating prescription must begin with postural support, which requires that equipment is first *sized* correctly and then *configured* appropriately to provide optimal musculoskeletal alignment and support. When postural support is provided with strategic selection and configuration of all seating system components, subsequent outcomes include optimized function, comfort, and skin protection, all of which are critical considerations for any wheelchair user. A successful seating system for the individual with SCI meets identified needs and preferences and, as a result, contributes to improved quality of life.

REVIEW QUESTIONS

- List three common problems encountered by individuals with SCI who rely on wheelchairs for primary mobility.
- List 10 key components that should be included in a seating evaluation for an individual with SCI.
- Explain why it is important to examine the current equipment used by a client during a seating evaluation.
- Describe the appropriate sequence in a seating intervention.
- What are the advantages of a fully customized ultra-light manual wheelchair?
- What is the primary feature that differentiates the power bases? How does this affect chair maneuverability and performance?
- Describe (three) beneficial features of power seat functions. For each of the independent power seat functions, name one relative concern.
- What are two key considerations when determining if an individual is best served with a manual or power wheelchair?

- How does a therapist determine the "best" cushion to prescribe to a particular client?
- Outline (three) critical elements to include when providing justification for a seating system.

REFERENCES

- Hobson DA, Tooms RE. Seated lumbar/pelvic alignment. A comparison between spinal cord-injured and noninjured groups. *Spine*. 1992;17(3):293-298.
- Alm M, Gutierrez E, Hultling C et al. Clinical evaluation of seating in persons with complete thoracic spinal cord injury. *Spinal Cord*. 2003;41(10):563-571.
- Finley MA, Lee RY. Effect of sitting posture on 3-dimensional scapular kinematics measured by skin-mounted electromagnetic tracking sensors. *Arch Phys Med Rehabil*. 2003;84(4):563-568.
- Massery M. What's positioning got to do with it? *Neurol Rep*. 1994;18(3).
- Samuelsson KA, Larsson H, Thyberg M et al. Back pain and spinal deformity—Common among wheelchair users with spinal cord injuries. *Scand J Occup Ther*. 1996;3:28-32.
- Boninger M, Waters RL, Chase T et al. *Preservation of Upper Limb Function Following Spinal Cord Injury: A Clinical Practice Guideline for Health-Care Professionals*. Washington DC: Paralyzed Veterans of America Consortium for Spinal Cord Medicine; 2005.
- Norkin C, Levangie P. *Joint Structure and Function a Comprehensive Analysis*. 2nd edition. Philadelphia: F. A. Davis; 1992.
- Greenfield B, Catlin PA, Coats PW et al. Posture in patients with shoulder overuse injuries and healthy individuals. *J Orthop Sports Phys Ther*. 1995;21(5):287-295.
- Keegan JJ. Alterations of the lumbar curve related to posture and seating. *J Bone Joint Surg*. 1953;35A(3):589-605.
- Matsen FA, Lippitt SB, Sidles JA et al. *Practical Evaluation and Management of the Shoulder*. Philadelphia: W. B. Saunders; 1994.
- Minkel JL. Seating and mobility considerations for people with spinal cord injury. *Phys Ther*. 2000;80(7):701-709.
- Seelen HA, Vuurman EF. Compensatory muscle activity for sitting posture during upper extremity task performance in paraplegic persons. *Scand J Rehabil Med*. 1991;23:89-96.
- Janssen-Potten YJ, Seelen HA, Drukker J et al. The effect of seat tilting on pelvic position, balance control, and compensatory postural muscle use in paraplegic subjects. *Arch Phys Med Rehabil*. 2001;82(10):1393-1402.
- Hastings JD, Fanucchi ER, Burns SP. Wheelchair configuration and postural alignment in persons with spinal cord injury. *Arch Phys Med Rehabil*. 2003;84:528-534.
- Sinnott KA, Milburn P, McNaughton H. Factors associated with thoracic spinal cord injury, lesion level and rotator cuff disorders. *Spinal Cord*. 2000;38:748-753.
- Boninger ML, Cooper RA, Shimada SD et al. Shoulder and elbow motion during two speeds of wheelchair propulsion: A description using a local coordinate system. *Spinal Cord*. 1998;36(6):418-426.

17. Boninger M, Baldwin M, Cooper R et al. Manual wheelchair pushrim biomechanics and axle position. *Arch Phys Med Rehabil.* 2000;81:608–613.
18. Boninger ML, Souza AL, Cooper RA et al. Propulsion patterns and pushrim biomechanics in manual wheelchair propulsion. *Arch Phys Med Rehabil.* 2002;83(5):718–723.
19. Rodgers MM, McQuade KJ, Rasch EK et al. Upper-limb fatigue-related joint power shifts in experienced wheelchair users and nonwheelchair users. *J Rehabil Res Dev.* 2003;40(1):27–37.
20. Massery M. Musculoskeletal and neuromuscular interventions: A physical approach to cystic fibrosis. *J R Soc Med.* 2005;98 Suppl 45:55–66.
21. McKinley WO, Jackson AB, Cardenas DD et al. Long-term medical complications after traumatic spinal cord injury: A regional model systems analysis. *Arch Phys Med Rehabil.* 1999;80(11):1402–1410.
22. Cardenas DD, Hoffman JM, Kirshblum S et al. Etiology and incidence of rehospitalization after traumatic spinal cord injury: A multicenter analysis. *Arch Phys Med Rehabil.* 2004;85(11):1757–1763.
23. Zacharkow D. Essential wheelchair modifications for proper sitting posture. *Wheelchair Posture and Pressure Sores.* Springfield, IL: CC Thomas; 1984. pp. 18–38.
24. Harms M. Effect of wheelchair design on posture and comfort of users. *Physiotherapy.* 1990;76:266–271.
25. Bolin I, Bodin P, Kreuter M. Sitting position—posture and performance in C5–C6 tetraplegia. *Spinal Cord.* 2000;38(7):425–434.
26. Janssen-Potten YJ, Seelen HA, Drukker J et al. Chair configuration and balance control in persons with spinal cord injury. *Arch Phys Med Rehabil.* 2000;81:401–408.
27. Janssen-Potten YJ, Seelen HA, Drukker J et al. The effect of footrests on sitting balance in paraplegic subjects. *Arch Phys Med Rehabil.* 2002;83(5):642–648.
28. Tomlinson JD. Managing maneuverability and rear stability of adjustable manual wheelchairs: An update. *Phys Ther.* 2000;80(9):904–911.
29. Tomlinson JD. Personal communication. Tacoma, WA; 2000.
30. Van Breukelen K. The ergonomic seating system. Paper presented at: 3rd International Congress on Restoration of (Wheeled) Mobility in Spinal Cord Injury, April 4, 2004; Amsterdam, The Netherlands.
31. Maurer CL, Sprigle S. Effect of seat inclination on seated pressures of individuals with spinal cord injury. *Phys Ther.* 2004;84(3):255–261.
32. Hastings JD. Seating assessment and planning. *Phys Med Rehabil Clin North Am.* 2000;11(1):183–207.
33. Hastings JD, Goldstein B. Paraplegia and the shoulder. *Phys Med Rehabil Clin North Am: Shoulder Rehabilitation, Part II.* 2004;15(3):699–718.
34. Kraemer H, Kraemer K. Designing, conducting, and analyzing programs within the prevention intervention research cycle. In: Mrazek PJ, Haggerty RJ, eds. *Reducing Risks for Mental Disorders, Frontiers for Preventive Intervention Research.* Washington DC: National Academy Press; 1994. pp. 359–414.
35. Bergstrom EMK. The effect of childhood spinal cord injury on skeletal development. *Spinal Cord.* 1999;37:838–846.
36. Putzke JD, Richards JS, Hicken BL et al. Interference due to pain following spinal cord injury: Important predictors and impact on quality of life. *Pain.* 2002;100(3):231–242.
37. Andersen JH, Kaergaard A, Frost P et al. Physical, psychosocial, and individual risk factors for neck/shoulder pain with pressure tenderness in the muscles among workers performing monotonous, repetitive work. *Spine.* 2002;27(6):660–667.
38. Frost P, Bonde JP, Mikkelsen S et al. Risk of shoulder tendonitis in relation to shoulder loads in monotonous repetitive work. *Am J Ind Med.* 2002;41(1):11–18.
39. Roquelaure Y, Mechali S, Dano C et al. Occupational and personal risk factors for carpal tunnel syndrome in industrial workers. *Scand J Work Environ Health.* 1997;23(5):364–369.
40. Fitzgerald SG, Cooper RA, Boninger ML et al. Comparison of fatigue life for 3 types of manual wheelchairs. *Arch Phys Med Rehabil.* 2001;82(10):1484–1488.
41. DiGiovine MM, Cooper RA, Boninger ML et al. User assessment of manual wheelchair ride comfort and ergonomics. *Arch Phys Med Rehabil.* 2000;81(4):490–494.
42. Cook AM, Hussey AM. Seating systems as extrinsic enablers for assistive technologies. *Assistive Technologies Principles and Practice.* 2nd ed. St. Louis, MO: Mosby; 2002.
43. Brubaker CE. Wheelchair prescription: An analysis of factors that affect mobility and performance. *J Rehabil Res Dev.* 1986;23(4):19–26.
44. Beekman CE, Miller-Porter L, Schoneberger M. Energy cost of propulsion in standard and ultralight wheelchairs in people with spinal cord injuries. *Phys Ther.* 1999;79(2):146–158.
45. Hughes CJ, Weimar WH, Sheth PN et al. Biomechanics of wheelchair propulsion as a function of seat position and user-to-chair interface. *Arch Phys Med Rehabil.* 1992;73(3):263–269.
46. Masse LC, Lamontagne M, O'Riain MD. Biomechanical analysis of wheelchair propulsion for various seating positions. *J Rehabil Res Dev.* 1992;29(3):12–28.
47. Richter WM. The effect of seat position on manual wheelchair propulsion biomechanics: A quasi-static model-based approach. *Med Eng Phys.* 2001;23(10):707–712.
48. van der Woude LH, Veeger DJ, Rozendal RH et al. Seat height in handrim wheelchair propulsion. *J Rehabil Res Dev.* 1989;26(4):31–50.
49. Cooper RA, Wolf E, Fitzgerald SG et al. Seat and footrest shocks and vibrations in manual wheelchairs with and without suspension. *Arch Phys Med Rehabil.* 2003;84(1):96–102.
50. Arva J, Fitzgerald SG, Cooper RA et al. Mechanical efficiency and user power requirement with a pushrim activated power assisted wheelchair. *Med Eng Phys.* 2001;23:699–705.
51. Cooper RA, Fitzgerald SG, Boninger ML et al. Evaluation of a pushrim-activated, power-assisted wheelchair. *Arch Phys Med Rehabil.* 2001;82(5):702–708.
52. Algood SD, Cooper RA, Fitzgerald SG et al. Impact of a pushrim-activated power-assisted wheelchair on the metabolic demands, stroke frequency, and range of motion among subjects with tetraplegia. *Arch Phys Med Rehabil.* 2004;85(11):1865–1871.
53. Levy CE, Chow JW. Pushrim-activated power-assist wheelchairs: Elegance in motion. *Am J Phys Med Rehabil.* 2004;83(2):166–167.
54. Algood SD, Cooper RA, Fitzgerald SG et al. Effect of a pushrim-activated power-assist wheelchair on the functional capabilities of persons with tetraplegia. *Arch Phys Med Rehabil.* 86;2005:380–386.

55. Corfman TA, Cooper RA, Boninger ML et al. Range of motion and stroke frequency differences between manual wheelchair propulsion and pushrim-activated power-assisted wheelchair propulsion. *J Spinal Cord Med.* 26;2003: 135-140.
56. Levy CE, Chow JW, Tillman MD et al. Variable-ratio pushrim-activated power-assist wheelchair eases wheeling over a variety of terrains for elders. *Arch Phys Med Rehabil.* 85;2004:104-112.
57. Best KL, Kirby RL, Smith C et al. Comparison between performance with a pushrim-activated power-assisted wheelchair and a manual wheelchair on the Wheelchair Skills Test. *Disabil Rehabil.* 2006;28(4):213-220.
58. Fitzgerald SG, Arva J, Cooper RA et al. A pilot study on community usage of a pushrim-activated, power-assisted wheelchair. *Assist Technol.* 2003;15:113-119.
59. Gordes KL, Finley MA, Meginniss S et al. Effect of two-speed manual wheel on shoulder pain in wheelchair users: Preliminary findings. Paper presented at: International Seating Symposium; 2006; Vancouver, BC.
60. Fass MV, Cooper RA, Fitzgerald SG et al. Durability, value, and reliability of selected electric powered wheelchairs. *Arch Phys Med Rehabil.* 2004;85(5):805-814.
61. Dennison I, Guyton D. Power wheelchairs—A new definition. Paper presented at: International Seating Symposium, 2002; Vancouver, BC.
62. Hobson DA. Comparative effects of posture on pressure and shear at the body-seat interface. *J Rehabil Res Dev.* 1992;29(4):21-31.
63. Vaisbuch N, Meyer S, Weiss PL. Effect of seated posture on interface pressure in children who are able-bodied and who have myelomeningocele. *Disabil Rehabil.* 2000;22(17): 749-755.
64. Stinson MD, Porter-Armstrong A, Eakin P. Seat-interface pressure: A pilot study of the relationship to gender, body mass index, and seating position. *Arch Phys Med Rehabil.* 2003;84(3):405-409.
65. Henderson JL, Price SH, Brandstater ME et al. Efficacy of three measures to relieve pressure in seated persons with spinal cord injury. *Arch Phys Med Rehabil.* 1994;75(5): 535-539.
66. Pellow TR. A comparison of interface pressure readings to wheelchair cushions and positioning: a pilot study. *Can J Occup Ther.* 1999;66(3):140-149.
67. Aissaoui R, Lacoste M, Dansereau J. Analysis of sliding and pressure distribution during a repositioning of persons in a simulator chair. *IEEE Trans Neural Syst Rehabil Eng.* 2001;9(2):215-224.
68. Lacoste M, Weiss-Lambrou R, Allard M et al. Powered tilt/recline systems: Why and how are they used? *Assist Technol.* 2003;15(1):58-68.
69. Arva J, Schmeler M, Lange M et al. RESNA position on the application of seat-elevating devices for wheelchair users. Rehabilitation Engineering Society of America. 2005. Available at: <http://www.rstce.pitt.edu>.
70. Kirby RL, Fahie CL, Smith C et al. Neck discomfort of wheelchair users: Effect of neck position. *Disabil Rehabil.* 2004;26(1):9-15.
71. Wang YT, Kim CK, Ford HT, 3rd et al. Reaction force and EMG analyses of wheelchair transfers. *Percept Motor Skill.* 1994;79(2):763-766.
72. Janssen WG, Bussmann HB, Stam HJ. Determinants of the sit-to-stand movement: A review. *Phys Ther.* 2002;82(9): 866-879.
73. Herberts P, Kadefors R, Hogfors C et al. Shoulder pain and heavy manual labor. *Clin Orthop Relat Res.* 1984(191): 166-178.
74. Sigholm G, Herberts P, Almstrom C et al. Electromyographic analysis of shoulder muscle load. *J Orthop Res.* 1984;1(4): 379-386.
75. Palmerud G, Forsman M, Sporrang H et al. Intramuscular pressure of the infra- and supraspinatus muscles in relation to hand load and arm posture. *Eur J Appl Physiol.* 2000;83(2-3):223-230.
76. Jarvholm U, Palmerud G, Karlsson D et al. Intramuscular pressure and electromyography in four shoulder muscles. *J Orthop Res.* 1991;9(4):609-619.
77. Sprigle S, Spasato B. Physiologic effects and design considerations of tilt and recline wheelchairs. *Orthop Phys Ther Clin North Am.* 1997;6(1):99-122.
78. Taub E. Somatosensory deafferentation in research with monkeys: Implications for rehabilitation medicine. In: Ince L, ed. Behavioural Psychology and Rehabilitation Medicine. Baltimore, MD: Williams & Wilkins; 1980. pp. 371-401.
79. Schmidt RA, Young DE. Methodology for motor learning: A paradigm for kinematic feedback. *J Motor Behav.* 1991;23(1):13-24.
80. Schmidt RA, Wrisberg CA. Motor Learning and Performance. 3rd ed. Champaign, IL: Human Kinetics; 2004.
81. Lotze M, Braun C, Birbaumer N et al. Motor learning elicited by voluntary drive. *Brain.* 2003;126(4):866-872.
82. Dyson-Hudson TA, Kirshblum SC. Shoulder pain in chronic spinal cord injury, Part I: Epidemiology, etiology and pathomechanics. *J Spinal Cord Med.* 2004;27:4-17.
83. Finley MA, Rodgers MM. Prevalence and identification of shoulder pathology in athletic and nonathletic wheelchair users with shoulder pain: A pilot study. *J Rehabil Res Dev.* 2004;41(3B):395-402.
84. Dalyan M, Cardenas DD, Gerard B. Upper extremity pain after spinal cord injury. *Spinal Cord.* 1999;37(3):191-195.
85. Samuelsson KA, Tropp H, Gerdl B. Shoulder pain and its consequences in paraplegic spinal cord-injured, wheelchair users. *Spinal Cord.* 2004;42(1):41-46.
86. Curtis KA, Tyner TM, Zachary L et al. Effect of a standard exercise protocol on shoulder pain in long-term wheelchair users. *Spinal Cord.* 1999;37(6):421-429.
87. Boninger ML, Cooper RA, Fitzgerald SG et al. Investigating neck pain in wheelchair users. *Am J Phys Med Rehabil.* 2003;82(3):197-202.
88. Hoxie R, Rubenstein L. Are older pedestrians allowed enough time to cross intersections safely? *J Am Geriatr Soc.* 1994;42(3):241-244.
89. Burns SP, Betz KL. Seating pressures with conventional and dynamic wheelchair cushions in tetraplegia. *Arch Phys Med Rehabil.* 1999;80(5):566-571.
90. Koo TK, Mak AF, Lee YL. Evaluation of an active seating system for pressure relief. *Assist Technol.* 1995;7(2):119-128.
91. Seymour RJ, Laceyfield WE. Wheelchair cushion effect on pressure and skin temperature. *Arch Phys Med Rehabil.* 1985;66(2):103-108.

92. Stewart SF, Palmieri V, Cochran GV. Wheelchair cushion effect on skin temperature, heat flux, and relative humidity. *Arch Phys Med Rehabil.* 1980;61(5):229-233.
93. Brienza DM, Geyer MJ. Understanding support surface technologies. *Adv Skin Wound Care.* 2000;13(5):237-244.
94. Aissaoui R, Kauffmann C, Dansereau J et al. Analysis of pressure distribution at the body-seat interface in able-bodied and paraplegic subjects using a deformable active contour algorithm. *Med Eng Phys.* 2001;23(6):359-367.
95. Yuen HK, Garrett D. Comparison of three wheelchair cushions for effectiveness of pressure relief. *Am J Occup Ther.* 2001;55(4):470-475.
96. Brienza DM, Karg PE, Geyer MJ et al. The relationship between pressure ulcer incidence and buttock-seat cushion interface pressure in at-risk elderly wheelchair users. *Arch Phys Med Rehabil.* 2001;82(4):529-533.
97. Sprigle S, Chung KC, Brubaker CE. Reduction of sitting pressures with custom contoured cushions. *J Rehabil Res Dev.* 1990;27(2):135-140.
98. Brienza DM, Karg PE, Brubaker CE. Seat cushion design for elderly wheelchair users based on minimization of soft tissue deformation using stiffness and pressure measurements. *IEEE Trans Rehabil Eng.* 1996;4(4):320-327.
99. Aissaoui R, Boucher C, Bourbonnais D et al. Effect of seat cushion on dynamic stability in sitting during a reaching task in wheelchair users with paraplegia. *Arch Phys Med Rehabil.* 2001;82(2):274-281.
100. Geyer MJ, Brienza DM, Karg P et al. A randomized control trial to evaluate pressure-reducing seat cushions for elderly wheelchair users. *Adv Skin Wound Care.* 2001;14(3):120-129, 131-122.
101. Dabnichki P, Taktak D. Pressure variation under the ischial tuberosity during a push cycle. *Med Eng Phys.* 1998;20(4):242-256.
102. Kernozek TW, Lewin JE. Seat interface pressures of individuals with paraplegia: Influence of dynamic wheelchair locomotion compared with static seated measurements. *Arch Phys Med Rehabil.* 1998;79(3):313-316.
103. Borg GA. Psychophysical bases of perceived exertion. *Med Sci Sports Exerc.* 1982;14(5):377-381.
104. Hastings JD. Instrument development: A postural scale for wheelchair users. *J Spinal Cord Med.* 2005;28(2):163.
105. Curtis KA, Roach KE, Applegate EB et al. Reliability and validity of the Wheelchair User's Shoulder Pain Index (WUSPI). *Paraplegia.* 1995;33(10):595-601.
106. Curtis KA, Roach KE, Applegate EB et al. Development of the Wheelchair User's Shoulder Pain Index (WUSPI). *Paraplegia.* 1995;33:290-293.
107. Mills T, Holm MB, Trefler E et al. Development and consumer validation of the Functional Evaluation in a Wheelchair (FEW) instrument. *Disabil Rehabil.* 2002;24(1-3):38-46.
108. Kilkens O, Post M, van der Woude LH et al. The wheelchair circuit: Reliability of a test to assess mobility in persons with spinal cord injuries. *Arch Phys Med Rehabil.* 2002;83(12):1783-1788.
109. Kilkens O, Dallmiejer A, De Witte L et al. The wheelchair circuit: Construct validity and responsiveness of a test to assess manual wheelchair mobility in persons with spinal cord injury. *Arch Phys Med Rehabil.* 2004;85(3):424-431.
110. Kirby RL, Swuste J, Dupuis DJ et al. The Wheelchair Skills Test: A pilot study of a new outcome measure. *Arch Phys Med Rehabil.* 2002;83(1):10-18.
111. Kirby RL, Dupuis DJ, Macphee AH et al. The Wheelchair Skills Test (version 2.4): Measurement properties. *Arch Phys Med Rehabil.* 2004;85(5):794-804.
112. Mentor R, Hudson L. Effects of age at injury and the aging process. In: Stover S, DeLisa J, Whiteneck G, editors. *Spinal Cord Injury: Clinical Outcomes from the Model Systems.* Gaithersburg, MD: Aspen; 1995. pp. 277-288.
113. Vogel LC, Krajci KA, Anderson CJ. Adults with pediatric-onset spinal cord injury: Part 2: Musculoskeletal and neurological complications. *J Spinal Cord Med.* 2002;25(2):117-123.

Appendix 8-1

Postural Scale for Wheelchair Users: Scoring and Metric Properties

The Postural Scale for Wheelchair Users provides a rating of the wheelchair user's perception of seating problems and concerns. The scale includes the domains of pain (P), aesthetics (A), health (H), and function (F).

Scoring Instructions

For each item, a box is checked to indicate agreement with the associated descriptor. The numerical values assigned to each checked box are transcribed in the associated triangle (on the right side). Vertical columns are added to obtain a summed score for each of the subscales. The subscale scores are summed for a total score.

The scale range is 0-48; subscale range is 0-12. A higher score indicates a perception of more problematic posture associated with seating.

A total score of 24 (50%) or greater, or a subscale score of 9 (75%) or greater, indicates that referral for seating evaluation and intervention would be of benefit to the wheelchair user.

Scale Metrics

Statistical testing of the Postural Scale for Wheelchair Users indicates high internal consistency (Cronbach's alpha = 0.86; subscale to scale: all significant [range = 0.76 - 0.86]; subscale to subscale: all significant [range = 0.40 - 0.72]; and item to subscale: all significant [range = 0.42 - 0.88]), and high test-retest reliability = 0.73.

Scale developed by Jennifer Hastings, PT, PhD, NCS

Postural Scale for Wheelchair Users

This is a questionnaire to assess how you feel about your posture. Please read each statement below and then determine how strongly you agree or disagree with the statement. Please check the box that matches the strength of your agreement/disagreement.

Type of wheelchair? Power _____, Manual _____

If you use both, select one for the purpose of the questionnaire.

	Completely Disagree	Somewhat Disagree	Somewhat Agree	Completely Agree	For administrative use only			
					P	A	H	F
1. Whenever I see a mirror I tend to correct my posture in my wheelchair.....	<input type="checkbox"/> 0	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3		<input type="checkbox"/>		
2. I feel sitting upright in my wheelchair is 'work'.....	<input type="checkbox"/> 0	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3	<input type="checkbox"/>			
3. I worry that how I sit may lead to skin breakdown	<input type="checkbox"/> 0	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3			<input type="checkbox"/>	
4. My wheelchair was custom-designed to meet my needs.....	<input type="checkbox"/> 3	<input type="checkbox"/> 2	<input type="checkbox"/> 1	<input type="checkbox"/> 0				<input type="checkbox"/>
5. I limit how long I sit in my wheelchair due to discomfort	<input type="checkbox"/> 0	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3				<input type="checkbox"/>
6. I think I could breathe easier if I sat differently.....	<input type="checkbox"/> 0	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3			<input type="checkbox"/>	
7. I have pain, or discomfort, that I think is related to how I sit in my wheelchair.....	<input type="checkbox"/> 0	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3	<input type="checkbox"/>			
8. I get tired during the day and I believe it is related to how I sit.....	<input type="checkbox"/> 0	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3	<input type="checkbox"/>			
9. I sit with my hips forward to improve my balance	<input type="checkbox"/> 0	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3				<input type="checkbox"/>
10. I think my posture may lead to some problems down the line	<input type="checkbox"/> 0	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3			<input type="checkbox"/>	
11. My chair is not supportive enough.....	<input type="checkbox"/> 0	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3				<input type="checkbox"/>
12. I think my muscular fatigue is due to how I sit in my wheelchair	<input type="checkbox"/> 0	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3	<input type="checkbox"/>			
13. I believe I have poor posture	<input type="checkbox"/> 0	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3		<input type="checkbox"/>		
14. I believe the way I sit makes my spasticity worse	<input type="checkbox"/> 0	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3			<input type="checkbox"/>	
15. I think I would look better if I could sit up taller.....	<input type="checkbox"/> 0	<input type="checkbox"/> 1	<input type="checkbox"/> 2	<input type="checkbox"/> 3		<input type="checkbox"/>		
16. I feel good about how I look in my wheelchair.....	<input type="checkbox"/> 3	<input type="checkbox"/> 2	<input type="checkbox"/> 1	<input type="checkbox"/> 0		<input type="checkbox"/>		
	Sums				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Totals =				<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Overall Total =				<input type="checkbox"/>			

Please fill out the following information:

Age _____ Neurological condition that requires use of a wheelchair _____
 (include level of injury if SCI)

Do you use your wheelchair full-time? ___Y ___ N

Year of beginning wheelchair use _____

Male ___ Female ___