Seating and Mobility Considerations for People With Spinal Cord Injury

For people with spinal cord injuries, the selection of a wheelchair and seating system involves many factors. This clinical perspective describes a model that includes consideration of the person, the wheelchair, the immediate environment between the person and the wheelchair, the intermediate environment of the home and work, and the community environment. The seated posture is examined biomechanically, and literature is reviewed that highlights the differences in the seated position of people with spinal cord injuries and people without spinal cord injuries. Reports regarding overuse injuries of the shoulder and wrists are discussed along with methods of relieving pressure at the buttock and seat interface. The impact that research findings should have on current clinical practice and the need for more research to provide evidence to either support or change current practice are discussed. [Minkel JL. Seating and mobility considerations for people with spinal cord injury. *Phys Ther.* 2000;80:701–709.]

Key Words: *Rehabilitation, Spinal cord injury, Wheelchair seating, Wheeled mobility.*

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According to Dr Lisa Iezzoni, "Walking is the unthinking transportation of daily life, supporting countless but essential trips within homes and beyond. Walking holds profound symbolic importance. Nowadays, upright movement permeates American aphorisms, connoting independence, autonomy, self-reliance, and strength."[1(p1609)] When a person sustains a spinal cord injury (SCI), often the most obvious functional limitation encountered is the loss of ambulation. The loss of this functional skill, in the context of the societal importance of "walking tall," creates a complex blend of the physical need to restore mobility and the emotional need to reframe one's "core sense of value and place in the world."[1(p1609)]

This relationship of self-identity with the ability to walk was illustrated in a qualitative study that examined ongoing changes in adaptive processes of a young man during initial rehabilitation after SCI.[2,3] A comparison of perspectives revealed that, whereas staff saw initiation of wheelchair sitting as an opportunity to increase mobility and sitting tolerance, the young man who was interviewed saw his wheelchair as a dreaded symbol of disability. In his words, "You might as well stick me in a damn closet. That wheelchair just makes me think of how helpless I am."[4(p91)]

Considerations for providing postural support in a wheelchair must be grounded in a functional context. The seated position, for many people with SCIs, will be the foundation from which they perform the essential activities of daily living, including tasks involving mobility. My intent in this article is to explore the frequently observed kyphotic sitting posture that is assumed by people with SCIs and the complex interplay between their posture, mobility, and environment.

Person-Device-Environment

Stiens[5] presents a model for understanding the impact that seating and mobility technologies can have on a person and the disablement process (Fig. 1). According to Stiens, the environment, as related to the person, can be divided into sectors:

- the immediate environment (the environment that is in direct contact with the person),
- the intermediate environment (personal space at home or at work), and
- the community environment (spaces modified for public use).

This model of person and environments correlates very well with both the proposed ICIDH-2 model (*International Classification of Impairments, Activities, and Participation*, from World Health Organization)[6] and the process of disablement (impairment, functional limitation, and disability) used as a framework in the *Guide to Physical Therapist Practice*.[7] To support a partnership in decision making, I believe that a clinician working with a person with SCI should focus, simultaneously, on multiple levels:

- the immediate environment to reduce or prevent an impairment (eg, prevent skeletal deformity and reduce the risks for tissue trauma),
- the intermediate environment to reduce functional limitations (eg, providing dynamic seating options and restoring functional mobility), and
- the community environment to reduce problems in participation and disability (eg, providing mobility training and consideration of transportation options in real world environments).

I believe that a seating and mobility assessment is better thought of as a jigsaw puzzle than as a cookbook. There is no one recipe that ensures success, rather the examination is a process of collecting interlocking pieces of information, recognizing when there are holes, and being creative in finding ways to fill the holes to facilitate the completion of the puzzle, a puzzle that is constantly shifting. Body shapes and sizes, as well as life goals and environments, change over time.[8] Each of these factors needs to be considered to ensure the effectiveness of a particular seating and mobility solution. Figure 2 illustrates the "big pieces" of the puzzle, which need to be gathered. Several textbooks describe the mechanics of an assessment process and can serve as reference tools for clinicians involved in recommending seating and mobility technologies.[9–12]

The Person and the Device

First-Time Versus Repeat Purchase of Seating and Mobility Systems

When providing seating and mobility interventions for a person with SCI, the timing of the intervention may affect the level of participation of the person and the role of the clinical professionals. The term "intervention" is used to describe an introduction to or a change of any or all components of the mobility base (wheelchair) or postural supports (eg, cushions). For many people with SCIs, the initial seating and wheeled mobility interventions may be viewed negatively. Participation by this person in the process may be limited. For clinicians, the full capabilities of a person are difficult to predict early in the rehabilitation process.[5] Emphasis

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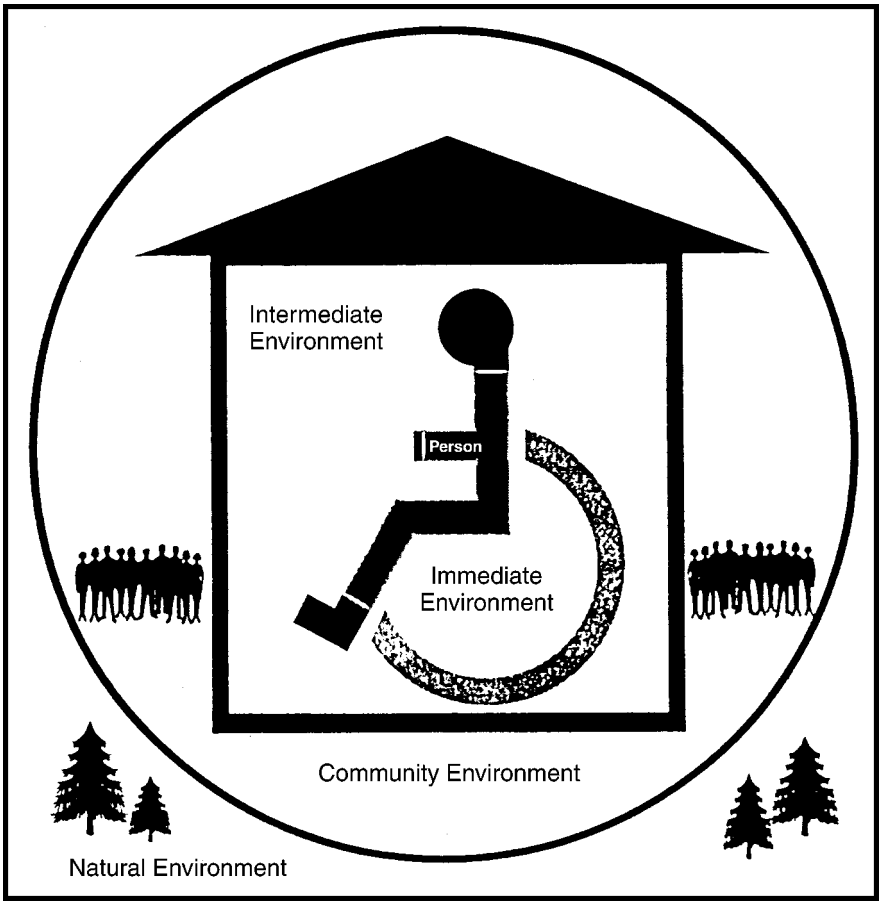

Figure 1.
The person and sectors of the environment. The diagram relates the person who experiences disablement to adaptive equipment and to his or her environment. The *environment* is outside the person. The *immediate environment* is directly in contact with the person and moves with the person (eg, clothes, adaptive equipment). The *intermediate environment* is the personal living space (ie, home) and work space (ie, office). The *community environment* is the space modified for public use. The *natural environment* is the space that has been minimally changed or left unaltered.

should initially be placed on the rehabilitation team's knowledge of the person's activity in environments before the injury. People purchasing their first wheelchair often rely on the team, including a supplier, for guidance. Recommendations are sought for seating and mobility systems that support increased independence in mobility and function. I believe that clinicians, while in this expert role, should look for ways to involve the person in product selection. To increase the client's involvement in the first-time purchase, I suggest providing an opportunity to "test drive" both the postural supports and the chairs, as well as discussing with therapists, the supplier, and other wheelchair users the potential advantages and disadvantages of available products and features.

In my experience, people who have lived with their disabilities for a while are often far more articulate about their expectations, needs, past experiences, and aspirations. The experienced wheelchair user needs to be recognized as a partner in the decision-making process. Often, this person will have individualized functional and environmental demands in which a new seating and mobility system must fit.

The Immediate Environment

Biomechanics of Seating and Postural Support

In their description of the biomechanics of seating, Carlson et al indicate the complexity of sitting upright against gravity:

> The unimpaired human trunk-neck-head complex receives its stability partly from the spinal column acting as a controlled stack of compression elements and partly from a multitude of muscles acting in several different ways. Muscle actions to constrict and control the circumference of the abdomen and thorax allow compressive body weight loads to be taken partly through the fluid-filled abdomino-thoracic cylinder rather than all acting down through the spinal column. This adds significantly to the stability of the torso.[13(p179)]

A person with an intact neuromuscular system is able to sit upright against gravity, without external supports, due to the intrinsic support provided by the action of muscles, tendons, and ligaments surrounding and supporting the spine and pelvis. A person without neuromuscular impairment easily moves in and out of various trunk positions while sitting; frequently moving from an upright "ready" position (for function) into a backward leaning "leisure" position (Linda Bidabee, M.O.V.E. International; personal communication). The active interplay of the internal, intrinsic supports provides for "hands-free" active sitting balance.

A person's ability to sit unsupported against gravity can be characterized by 1 of 3 levels:

- hands-free sitting,
- hands-dependent sitting, for people needing at least one upper extremity for support, or
- prop sitting, for people needing external support beyond the use of their upper extremities.

The level of the injury for a person with an SCI affects the extent to which the abdominal-thoracic muscle

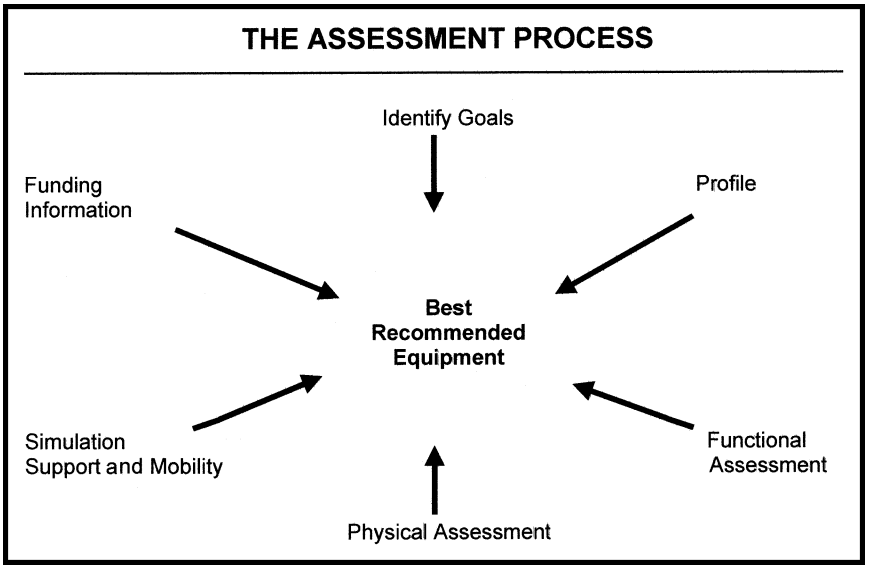

Figure 2.
Components of an assessment.

complex can provide intrinsic postural support and contribute to active sitting balance. The following are based on my observations:

- People with a high cervical-level injury (C1-C4) have little to no active sitting balance and are unable to use their upper extremities as secondary supports. People with an injury at these levels use prop sitting and need extensive, external support, often including head and neck support, to maintain an upright sitting posture.
- People with lower cervical-level (C5-C8) and high thoracic-level (T1-T8) injuries are often able to use their upper extremities as secondary supports. When these people are asked to lift both arms at the same time, however, their trunks may assume a compensating position to allow the person to stay upright in sitting without upper-extremity support. A person who sits with hands dependent may need both posterior and lateral trunk support when sitting in a chair, for functional use of the upper extremities, without the compensation in the trunk.
- People with low thoracic-level (T9-T12) and lumbar/sacral-level injuries often have sufficient intact trunk muscle activity to easily lift both arms in an unsupported position and maintain an erect trunk position. These people often frequently change their sitting posture, freely moving in and out of forward leaning to backward leaning positions. Many may choose to use posterior support for low back support while sitting in a chair.

A frequently observed compensatory trunk position, seen in people who use prop- and hands-dependent sitting, is the long "C"-shaped kyphotic thoracolumbar spine, flattened lumbar spine, and posteriorly tilted pelvis. In this position, a person has increased his or her base of support by posteriorly rotating the pelvis. The result is that the center of gravity of the trunk is shifted behind the base of support, thus achieving sufficient trunk stability to allow the person to lift his or her arms, if able.[14(p6),15] While sitting in a standard, sling-back wheelchair, a person with compromised sitting balance is able to "sink" into the sling (using the kyphotic trunk position for stability) and use his or her arms for propulsion or other bilateral upper-extremity functional activities. When increased trunk support is needed (eg, when descending an incline), the person who sits with hands dependent will often hook one arm around the push handle on the back of the wheelchair. The person who prop sits may need to be reclined or tipped backward before feeling stable enough to descend the incline. These compensations underscore the importance of achieving postural stability while sitting to perform functional activities.

There are many important reasons for providing external support that counteracts the tendency of people with SCIs to sit in kyphotic positions. Zacharkow[14(pp18–38)] noted consistently cited concerns relating to persistent kyphotic posturing: (1) increased risk of pressure sore formation, (2) compromised diaphragmatic breathing, and (3) increased risk of posterior neck pain from trying to keep the head up to look straight. Zacharkow recommended a basic sitting posture that will hold the individual securely in the wheelchair. This posture is achieved by angling the seat and backrest backward in space (10°–20° back from the vertical), setting the seat to a backrest angle of 95 degrees, and using a lumbar support.

The results of several studies,[15–17] however, have indicated that the sitting postures assumed by people with SCIs are biomechanically different than the postures assumed by people without SCIs. In their work on lumbar support thickness, Shields and Cook[16] found an interaction between subject groups (ie, people with SCIs versus people without SCIs) and lumbar support conditions. A videotape recording of the subject's interface pressure (between the buttock and a solid seat), detected on a barograph chair, illustrated the changes in pressure distribution (viewed on a color monitor as overlapping concentric rings) when using various sizes of lumbar supports. In addition, the hip angle (pelvi-

femoral angle) was measured during each lumbar support condition and compared within and between subject groups. Subjects were well matched in terms of height and weight between the 2 groups.

The results of the study by Shields and Cook[16] indicated that the highest pressure areas at the buttock were greater in the subjects with SCIs than in the comparison group for all lumbar support conditions. The subjects without SCIs showed greater than 90% reduction in the mean highest buttock pressure area when using a 7.5-cm-thick lumbar support as compared with the mean highest buttock pressure when no lumbar support was being used. The subjects with SCIs, however, showed no change in the highest interface pressure level, regardless of the thickness of the lumbar support. In addition, the hip flexion angle (pelvifemoral angle) was lower for the subjects with SCIs than for the comparison group. The authors observed that "the inability of individuals with chronic SCI (more than 3 years postinjury) to sit with a similar initial hip flexion as nondisabled subjects may, in part, explain the negligible effect of the thickness of the lumbar support on the highest seated buttock pressure."[16(p225)]

Similar observations were also reported by Hobson and Tooms,[15,17] who found the mean maximal buttock interface pressure also to be 6% to 46% higher (depending on posture) for individuals with SCIs as compared with individuals without SCIs. Although Hobson and Tooms[15] did not measure the pelvifemoral angle, the data from their study suggest the presence of a similar kyphotic sitting posture. In general, the center of gravity of individuals with SCIs was displaced farther posteriorly when compared with that of individuals without SCIs. In addition, people with SCIs, on average, sat in a posture with a posteriorly rotated pelvis. Hobson and Tooms[15] found that the pelvis was tilted 15 degrees more in people with SCIs than in people without SCIs. Each of these studies[15–17] provides evidence that people without SCIs should not be subjects in studies examining how people with SCIs respond to an intervention.

Intervention Strategies

Postural supports. Postural supports mounted on a wheelchair for a person with SCI should match the available passive range of motion and sitting balance skill while performing functional activities. The sitting posture described by Zacharkow[14(pp18–38)] may not match the needs of all individuals. I believe that a supine examination to determine joint flexibility and an examination of supported sitting, with the therapist using his or her hands to simulate the location, type, and direction of support needed, can provide the information needed to determine what postural support system is needed for a given person. These examinations allow the clinician to determine the presence or absence of skeletal deformity and whether the deformity is fixed or flexible.

A person in a kyphotic sitting position may need 1 of 2 types of seating support if the examinations indicate that the curve is flexible as opposed to fixed. For a person whose spine is flexible enough to be passively moved out of the kyphotic position, the postural support, in my opinion, should be designed to provide corrective support to increase spinal extension and maintain an upright trunk position. For the person who has lost this flexibility and who has a fixed kyphotic posture, I contend that the postural supports should accommodate the trunk position. Rather than attempting to apply any corrective forces to extend the trunk, the intervention for the fixed curve, in my view, should be contoured to match the size and location of the spinal curve. Shields and Cook[16] and Hobson and Tooms[15,17] found that the pelvic mobility out of a posterior tilt, the available hip flexion range of motion, and the amount of lumbar mobility are different in people with SCIs than in people without SCIs. Therefore, in my opinion, an individualized, hands-on assessment is critical for:

- determining the pelvifemoral angle (range of motion between the femur and acetabulum) and then matching this angle to the seat-to-backrest angle of the chair,
- measuring the amount of mobility in the lumbar and thoracic regions in order to determine whether postural supports should be used to reduce a flexible deformity or to provide accommodation to a fixed limitation, and
- establishing the position of the pelvis, trunk, and head when the person is supported in sitting in order to determine the orientation of the seat and backrest.

Tissue integrity. Zacharkow[14(pp18–38)] referred to the increased risk of pressure sore formation as a serious concern in people with a persistent kyphotic posture. When seated in this position, a person's weight-bearing area shifts from the broader area of the ischial tuberosities to the much smaller area of the sacrum and the spinous processes at the apex of the kyphosis.[14–17] This reduction in surface area results in an increase of pressure over the sacrum, and thus an increase in the risk of tissue trauma. Providing postural support, maintaining tissue integrity, and preventing tissue trauma are critical considerations in determining which wheelchair and support system should be used. Posture is not often the sole cause of skin breakdown, but attention to the person's sitting posture and the need for postural support is an important component of any tissue management program.

As indicated by the multisystem assessment used in the Braden Scale for Predicting Pressure Sore Risk,[18] there are many potential causes of skin breakdown. Each of these factors—sensation, moisture, nutrition, activity, mobility, friction, and shear—needs to be carefully evaluated when working with a person who is at risk for tissue trauma. For the purpose of this article, I am focusing on pressure relief for people without sensation.

One factor that appears to contribute to tissue trauma is pressure, that is, the direct loading of soft tissues by internal bony prominences. Pressure is one of the easier factors to measure.[10] Increasingly, I believe, therapists working in seating clinics use tools to measure the interface pressure between the seat surface and the buttock. These tools include pressure mapping systems,[19] which display information about the entire seating surface, and discrete pressure sensors,[20] which measure pressure under specific bony areas. These tools provide a method of measuring the distribution and magnitude of pressure at the interface between the seated individual and the support surface. While observing the display of a mapping system, it is easy to see the redistribution of pressure away from the ischial tuberosities and onto the sacrum, as a person slides from an upright sitting position into a slumped kyphotic posture. As noted earlier, as the surface area supporting a person's weight becomes smaller, the interface pressure between the sacrum and the support surface rises.

The magnitude of the interface pressure may be less critical than the length of time that this pressure is consistently applied or is uninterrupted.[20] The ability to periodically relieve the pressure under a bony prominence is an important functional skill and should be part of a complete program for maintaining skin integrity.

For people who have a complete SCI and who lack sensation, I believe the shifting of body weight while sitting needs to become a conscious activity. People with sufficient upper-extremity muscle force, historically, were taught to do a push-up from the armrests or the tires of the wheelchair in order to unweight their buttock and "relieve pressure." There is, however, increasing evidence of overuse injuries of the shoulder and wrists with aging in people with SCIs.[21–23] In addition to the repetitive motion associated with propelling a manual wheelchair, the strains on the shoulder during transfers and repeated push-ups are felt to contribute to this reported shoulder pain.[24]

Henderson et al[25] compared 3 methods of relieving pressure in seated people with SCIs. A pressure mapping system was used to evaluate the pressure changes with the subjects:

- seated in a chair tipped backward by an assistant to 35 degrees,
- seated in a chair tipped backward by an assistant to 65 degrees, and
- seated in a chair leaning forward with the chest toward the thighs.

Their results indicate that the greatest pressure relief over the ischial tuberosities was seen in the forward leaning position. Pressure relief was also shown in the 65-degree backward tilt position, whereas only a minimal drop in ischial pressure was observed with a backward tilt of 35 degrees.

For people who sit using a push-up to relieve pressure, leaning forward or to either side may be less stressful on the shoulder and may be a preferred, long-term method of relieving pressure. For people who prop sit and others who are not able to independently recover from the forward leaning position and for whom lateral shifts are not effective, a self-operated, mechanical method of unweighting the buttocks may be indicated. Power seating options are available that allow the person to tilt the seat backward or to recline the backrest (opening the seat to backrest angle), and there are even some products that allow the user to both tilt and recline. Henderson and colleagues' results[25] suggest that the power tilt systems need to tilt past 35 degrees and perhaps as much as 65 degrees to effectively unweight the buttock. Regardless of the method used, a self-operated mechanical method of pressure relief appears to be critical to people who are unable to physically shift their weight in order to be in control of and responsible for the condition of their skin.

The Intermediate Environment

The purpose of seating in a wheelchair is not just to provide skeletal support or to maintain skin integrity, but more importantly to enhance function. A person's home and work environments can be highly customized to provide easier function. For many wheelchair users, modifications to widen doorways, ramp steps, and rearrange furniture allow for easy physical access to their routine environments. Functioning in these environments is easier, however, if the wheelchair user has the options to dynamically change sitting postures by physical movement or use of power seating (tilt or recline).

Observation of a person who sits with his or her hands free demonstrates that a variety of positions are assumed, and they are often related to the type of activity in which the person is involved. Observing people who are active, independent manual wheelchair users, one notices how they frequently shift their body position within the wheelchair and shift the wheelchair's position in space. When involved in a desk activity, he or she will often sit

on the front edge of the seat and lean the trunk forward. When relaxing and seeking a position of leisure, he or she can be observed in a "wheelie" position, that is, resting back in a tilted position, with the casters of the wheelchair off the ground. For people with sufficient trunk control, these dynamic sitting variations assist in completing numerous daily activities in and around home and work.

For the person who has a higher level of SCI and who is not able to physically shift his or her own body position in the chair, therapists should consider power seating options (ie, power tilting or reclining) as a method of achieving similar sitting variations. Using a mechanical assist from power seating, a person may be able to independently move from an upright position, again perhaps to improve access to a desktop, and then back into a more leisurely position. The range of postural adjustments that people with SCIs use while sitting, in my view, are often much smaller than the range needed to unweight the ischial tuberosities in order to perform a pressure-relief maneuver. I contend that a person using a mechanical means of seating may need to be reminded to perform a full weight shift, in addition to adjusting his or her position for functional activities.

Community Environment

In his model of the person and sectors of the environment, Stiens[5] describes the community environment as space modified for public use. In recent years, due in part to the Americans With Disability Act, community environments have become increasingly accessible for people who use wheeled devices as their primary means of mobility. Although community accessibility has greatly improved, the impact of long-term manual wheelchair propulsion (perhaps, in part, due to propelling the longer distances that are now accessible in the community) is having a negative effect on the integrity of the shoulder and wrist joints with aging in people with SCIs.[21–24] For many, an effective conservative treatment for shoulder and wrist pain is to decrease the use of a manual wheelchair and begin using a power wheelchair, especially for long distances. This treatment approach is not always readily embraced by the long-term user of a manual wheelchair.

Frequently, one hears "use it or lose it" as the reason for not making the transition to power wheelchairs. Many people interpret the change from a manual wheelchair to a power wheelchair as an indication of greater disability, rather than as an option for increased capability.[26] Yet, many people who have made the transition, or are using power mobility part-time, admit that conceding their need for assisted mobility was the hardest part. After surmounting that hurdle, the world literally opened up for them. The new power wheelchair user often experiences a burst of energy, once precious muscle force is no longer spent merely getting around.[1,27] Taking a longer-term approach, protecting the integrity of the shoulder joints and including community mobility demands in a functional analysis could influence the initial recommendations regarding the use manual or power mobility for a person with an SCI. Perhaps we need to embrace the concept of combining manual and power mobility by exploring the use of a manual wheelchair *and* a power wheelchair to meet the personal and community mobility demands of an individual.

Mobility Training

A survey conducted by Gaal et al[28] indicates the importance of providing wheeled mobility training in a community environment. Gaal et al surveyed 109 active wheelchair users who had experienced an incident while riding in a wheelchair. An *incident* was defined as an event that interrupted normal wheelchair operation and, in the user's judgment, either caused injury or posed the threat of injury. The authors categorized incidents as tips and falls, component failures, or "other" incidents, including being struck by car, incidents involving the tie-down system used during transportation, van or bus lift incidents, or a collision with an immovable object. A total of 253 incidents were reported by the 109 participants. Tips and falls accounted for 42% of the total number of reported incidents. The direction of fall, however, differed between power and manual wheelchair users. Manual wheelchairs tended to tip forward and backward, whereas power wheelchairs tipped sideward. Forward and sideward falls were associated with injuries that required medical attention, whereas backward falls did not. The riding surface was an important factor in the tips and falls. Ninety percent of the reported forward falls involved the specific case of riding through a sudden slope transition from downhill to uphill, such as at the bottom of a curb cut.

Today, manual and power wheelchairs offer much in the way of adjustability of features to customize their performance. Once the wheelchair is adjusted, however, I believe that the wheelchair user needs instruction on indoor and outdoor mobility skills,[29] which will assist the person to make the most of the adjustments and to understand the limits of his or her mobility skills in order to reduce the risks for tips and falls. Axelson, a wheelchair user himself, and colleagues[29] provide guidance not only on how to perform a variety of mobility skills but also on how to provide "spotting" for someone who is learning new skills.

Transportation

For many people with SCIs, proficiency in wheelchair use restores only part of the mobility they need to

increase social participation and thus decrease their level of disability. For many people with SCIs, personal transportation, of themselves and their chair, is a critical link to restoring independence and enhancing quality of life. I have observed that access to personal transportation, whether as a driver or as a passenger, makes an impact on the level of disability (participation) experienced by the person with SCI. Options in personal transportation cover a broad array of vehicle types, including 2-door sedans, minivans, and highly customized full-sized vans, and accessible public transportation. Like so many aspects of equipment recommendation, the choice is based on balancing multiple factors. These factors include, but are not limited to, available financial resources, transfer techniques of the wheelchair user, the individual's potential to drive, and the type of wheelchair being used.

Transportation options are critical for both the new wheelchair user and the repeat purchaser. For the new wheelchair user, the type and size of the initial wheelchair often set the limits around which the personal transportation system must be designed. For the repeat purchaser, the personal transportation system may limit options for new seating and mobility systems. For people who are considering a change to, or the addition of, power mobility, the transportation concerns about the power wheelchair need to be considered.

Conclusion

According to Spencer et al, "Clearly, assistive technology does not and will not answer all problems associated with disabling conditions. Nevertheless, when assistive technology is well designed, taught in appropriate context, made affordable, and accepted by the consumer, the lives of individuals with disabilities are enhanced."[3(p62)] Seating and mobility technologies, like all other assistive technologies, are tools that are available to people with SCIs to allow exploration of options to reframe their "core sense of value and place in the world."[1]

During the past 20 years, many new products designed to provide postural support and wheeled mobility have become commercially available. With so many options, clinicians should look for evidence to support clinical practice. Keeping in mind the immediate, intermediate, and community environments, outcomes need to measure the function and quality of life that interventions provide to people with SCIs. These outcomes need to be documented in a manner that includes not only the impact but also the cost of providing the assessment, the products, and the training. Incorporating tools such as pressure mapping systems, using clinical practice backed by evidence, and documenting actual long-term outcomes are important strategies for meeting the seating and mobility needs of a person with SCI. Although several studies are discussed in this article, much more research is needed to guide the clinical interventions used for postural support and improved mobility. Critical to all clinicians and their clients is the incorporation of these research findings into routine clinical practice.

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