Recommendations for Mobility in Children with Spinal Cord Injury

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Background: Mobility is an important aspect of the rehabilitation of children with spinal cord injury (SCI), is a necessary component of life, and is critical in a child's development. Depending upon the individual's age and degree of neurological impairment, the nature of mobility may vary. **Objectives:** The objective of this article is to establish recommendations surrounding the selection of mobility for children with SCI. **Methods:** Extensive literature review and multidisciplinary peer review. **Results:** Types of mobility including power, manual, upright, and community are discussed, and recommendations are made based on medical necessity, neurological level, ASIA Impairment Scale score, and developmental considerations and challenges. **Conclusion:** Mobility is critical for proper development to occur in the pediatric population, and it may be challenging to make recommendations for mobility in children with SCI. It is essential for clinicians providing care to children with SCI to address mobility in a comprehensive and longitudinal manner across the children's environments. **Key words:** *mobility, pediatric, spinal cord injury*

Mobility is an important aspect of the rehabilitation of children with spinal cord injury (SCI), is a necessary component of life, and is critical in a child's development. The concept of mobility should be viewed in a comprehensive manner that goes beyond ambulation to include effective mobility in all spheres of life, including home, school, community, and the world at large. Depending upon the individual's age and degree of neurological impairment, the nature of mobility may vary. However, the broad categories of mobility ranging from bed mobility and transfers to movement at home, in school, and in the wider community apply to all ages and all degrees of neurological severity. Initially, mobility facilitates cognitive, social, and communication skills. As children age, mobility significantly impacts activity and participation specific to each developmental stage that are critical to successful progression throughout childhood and adolescence. For a toddler, mobility accomplished through crawling and walking is critical in children's development allowing them to explore their environment; hence, impairment of mobility as a result of an SCI may interfere with critical developmental milestones during early childhood. At the other age extreme of pediatric-onset SCI, adolescents with SCI may not have the opportunities to spontaneously access community activities that non-injured peers experience, such as "hanging out," because of their mobility limitations.

As a result of SCI, children are often unable to ambulate. If a child is unable to independently and safely ambulate, he or she needs an alternate means of mobility. Most individuals who sustain an SCI will require a power or manual wheelchair as a means of mobility; the type of wheelchair needed is dependent upon the child's level of injury and functional status. Many factors must be considered when determining an appropriate form of wheeled mobility for a child with an SCI, including age, level and severity of injury, environment, and child and family preferences. In addition to wheeled mobility, upright mobility facilitated by lower extremity orthotics and/or locomotor training is an option for therapeutic, household, and/or community ambulation.

The goals and specific modes of mobility will change as a function of physical size, cognition, personal and family preferences, and functional and social needs. As a result, individuals must be re-evaluated periodically to evaluate their current mobility status and prescribe appropriate modifications or new modalities that are appropriate for current and future needs. Throughout development, children and their parents should be provided anticipatory guidance on potential needs and alternatives. In addition, because of the physical, physiologic, and

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psychosocial growth of children, it is important to evaluate the appropriateness and fit of orthotics, standing frames, and wheelchairs over time.

Types of Mobility

Power mobility

Aspects of power wheelchairs that should be considered include the base, drive control, and seat functions. There are 3 options for placement of the drive wheels on a power wheelchair: front, rear, and mid or center wheel drive. With a front wheel drive configuration, the main drive wheel is located in the front and the majority of the chair is behind the user. When this chair is driven, there is more of a pulling motion since the front wheels are pulling both the chair and the user. This type of chair is good for uneven terrain and hills, but it has a slower top speed when compared to the other 2. With a mid or center wheel drive configuration, the main drive wheel is located more centrally, typically under the individual operating the chair. This type of base has a smaller turning radius to maneuver in tight spaces. With a mid or center wheel drive chair, there is less chair around the driver, resulting in less chair that needs to be judged for maneuvering the chair. With rear wheel drive, the main drive wheel is located in the back and the majority of the chair is in front of the user. When this chair is driven, there is more of a pushing motion than a pulling motion. It is a very stable chair for most circumstances and terrain and has a higher top overall speed compared to the other 2 chairs. Additionally, it is the most stable type of chair for power tilt, which is frequently necessary for individuals with SCI.

Physical limitations should not rule out the use of a power wheelchair. Drive controls can be fabricated to access any body part. Drive controls require electronic programming to provide control of speed, acceleration, deceleration, braking, and torque. They should be adjusted based on the environment. Drive controls include, but are not limited to, switches, head array, sip and puff, mouth and tongue pieces, mini proportional joysticks, and standard joysticks.

Power seat functions can be used to optimize functioning and promote independence, allow for positional changes and pressure relief, assist with environmental access, provide comfort and pain relief, decrease fatigue, and affect physiologic functioning. The tilt function keeps the individual in the seated position but provides movement in space. The tilt/recline feature will allow tilt as previously mentioned and will open the seat-to-back angle allowing the individual to lie back. For some, this position may provide easier access for bladder management and hygiene, respiratory care, and management of orthostatic hypotension. Because of the shear potential inherent in a recline system, mechanical shear reduction is available. With shear reduction, the mechanical component of the backrest and the user interface of the backrest move relative to one another while in the recline position, therefore reducing shear on the user. A standing function will bring the user into standing, which allows for weight bearing. In addition to providing increased environmental access, a seat elevator can assist with transfers. A seat-to-floor function can allow a child to access lower surfaces, which can be especially important for peer interaction in younger children, and allow the child to crawl into the chair. Power elevating leg rests can increase ground clearance and may provide circulatory benefits and edema control when used in conjunction with tilt or recline.

Although a scooter is not traditionally recommended for children with SCI, it may be considered for individuals with mobility or endurance impairments who do not require much postural support or pressure relief. Scooters cost less than power wheelchairs in general, but they are not an appropriate choice for most children and adolescents with SCI.

Manual mobility

There are 2 options regarding the selection of a manual wheelchair frame: rigid or folding. A rigid frame does not fold, although some have the ability for the back to fold down on the seat. Rigid frames are usually lighter than a similar folding chair due to less moveable parts and are also more durable. A folding frame has the ability to fold in half via a cross brace underneath the seating system for stowing or transport. This type of frame contains more adjustable and moveable parts than a rigid frame and often does not meet a child's sports and/or leisure needs.

Push rim–activated power assist wheels and a battery pack can be added to a manual wheelchair frame to provide assistance to the user during propulsion. There are motors located inside the wheels that are activated via sensors in the push rims. The wheels give the user the ability to customize touch sensitivity, speed, and the amount of assistance required. Additionally, these wheels can prevent backward rolling when ascending an incline.

The use of strollers should be limited to infants and toddlers, which are the ages when strollers are commonly utilized for those without mobility limitations. Children, as young as 1 year of age, should be encouraged to utilize a power or manual wheelchair to facilitate independence.

Walking and upright mobility

Standers

A stander is commercially available and usually includes a seat that the user transfers into or a pelvic strap that allows the user to stand directly from the wheelchair. A manual, hydraulic, or electric lift is used to bring the individual to standing. Lower extremity, trunk, chest, and upper extremity supports are available as needed. Types of standers include static, mobile, and active, which allow for upper extremity strengthening and lower extremity range of motion while standing. A parapodium is an orthotic device often used for very young children, as long as sufficient head control is present. It is designed for standing and moving short distances without the use of an assistive device, thus freeing up the patient's arms and hands for functional use. The hip and knee joints of the parapodium flex and allow for sitting while in the device.

Orthotics

An ankle-foot orthosis (AFO) is a type of lower extremity orthosis that provides ankle and foot support for the user who has sufficient hip and knee strength to control the knee during stance and swing. Numerous types of AFOs are available based on the type of support the user requires; they can be adjustable or fixed for greater ease based on the types of functional activities the user is able to do. They may attach to a shoe or be used as an insert into a shoe. AFOs may be fabricated of carbon fiber, plastic, metal components, or a combination. They may be used unilaterally or bilaterally. A knee-ankle-foot orthosis (KAFO) provides knee, ankle, and foot stability. KAFOs may be fabricated of carbon fiber, plastic, or leather with metal uprights and may attach to shoes or be used as an insert into shoes. This type of orthosis may be used unilaterally or bilaterally. A hip-knee-ankle-foot orthosis (HKAFO) stabilizes at the hip, knee, and ankle. It consists of a pair of KAFOs attached to one another by a pelvic band or trunk orthosis. With the hip component locked, support is provided in the transverse and sagittal planes and a swing to/through gait pattern is used. With the hip component unlocked, the user may be able to ambulate with a reciprocal gait while still receiving stability in the transverse plane. HKAFOs may be fabricated of carbon fiber, plastic, or leather with metal uprights. They may be attached to shoes or inserted into shoes; they are more difficult to donn/doff than the orthoses listed previously, especially when they include the bilateral leg pelvic attachment. A reciprocating gait orthosis (RGO) is a pair of HKAFOs that are connected to one another by an isocentric bar and a cable system, allowing the user to ambulate with a dynamic reciprocal gait using body weight shifts to unload one side of the body and activate the opposite side. This orthosis may be attached to shoes or used as an insert into shoes; it may be difficult to donn/doff due to bilateral and pelvic attachments.

Functional electrical stimulation (FES) systems provide activation of muscle groups to allow for functional activities such as walking without foot drop, standing, or reciprocal walking patterns via surface stimulation of specific nerve/muscle groups. Currently, 2 types of commercial units are available: a foot drop system and a foot drop plus thigh weakness system. Pediatric and smaller sizes are available. In addition, portable neuromuscular electrical stimulation (NMES) devices can be used for more customizable programs.

Locomotor training (LT) is a type of therapeutic modality involving continuous repetition of the lower extremities to complete a meaningful task such as walking. Recently, the use of LT has been studied and used clinically to facilitate walking recovery in individuals with neuromuscular impairments. LT is often initiated with a body weight–supported (BWS) system and a treadmill. This decreased weight of the individual makes stepping easier. The BWS system includes an overhead support with harness attachment. LT may be conducted manually with therapists or robotic-generated mechanisms helping to move the lower extremities. Robotic gait orthoses can be programmed to train the individual specific to his or her needs. In addition to BWS LT on the treadmill, the therapy can also be conducted over ground. Progression of LT may occur via increased walking speed and/or distance, decreased body weight support, decreased manual assistance, and increased therapy and ambulation over ground. It is important that ambulation training progress to over ground in order to have carryover into functional activities and tasks.

Community mobility

Ready access to the community is important at all ages, but it becomes most critical in adolescence. Whether public or private, motorized transportation must be accessible and enhance an adolescent's independence. Although individuals with lesions as high as C5 are capable of driving an appropriately adapted motor vehicle, it is imperative that they receive a proper driver evaluation and obtain appropriate prescriptions for motor vehicle adaptations. The age at which adolescents can obtain a driver's permit and eventually a driver's license varies between countries as well as regions or states, but generally it is 16 to 18 years of age.

Adolescents with paraplegia should be able to transfer independently from an ultra-lightweight manual chair to the driver's seat of a motor vehicle and then transfer the wheelchair into the car. Most adolescents with tetraplegia, especially those who utilize power wheelchairs, will need an adapted van with a wheelchair lift and an automatic locking system for their wheelchair, either in the driver's position or as a passenger. Using an adapted van with a wheelchair lift, adolescents with tetraplegia or paraplegia who utilize a manual wheelchair would generally transfer themselves into the driver's seat. If the adolescent transfers onto the motor vehicle seat, their pressure-reducing seating system should be utilized.

Individuals of all ages with spinal cord dysfunction should be properly restrained in motor vehicles. These restraints range from car seats for infants and toddlers, boosters for older children, specialized restraint systems for children with poor trunk or neck control, and 3-point restraints for appropriately sized older children and adolescents to approved restraint systems for those who remain in their wheelchairs that are properly locked down.

Medically Necessary and Medically Beneficial Mobility Recommendations for Children with SCI

When determining an appropriate form of mobility for a child, many factors must be considered. A comprehensive examination includes an assessment of functional abilities and limitations, neuromusculoskeletal status, the child's home and school environments, and financial coverage. These factors as well as input from the child and parents/caregivers should be considered in determining all functional implications for the use of the wheelchair (ie, transport, transfers, accessibility, etc) and aesthetics. An evaluation for a permanent wheelchair and seating system is often completed during the initial inpatient rehabilitation. The child should be provided the opportunity to trial several types of appropriate wheelchairs and seating systems before a final decision is made. If significant neurological change is anticipated, the definitive wheelchair evaluation should be postponed to allow for the most appropriate selection. Manual wheelchair users should be provided with a high strength, fully customizable wheelchair frame made of the lightest possible material.[1] The axle should be adjusted as far forward as possible without compromising stability and positioned so that when the hand is placed at the top center position of the push rim, the angle between the upper arm and forearm is 100° to 120°.[1] A properly configured wheelchair via custom modification has significant implications such as decreased incidence of upper extremity strain and injury and effects on mechanical efficiency and oxygen cost/use.[2]

Prior to recommending any type of orthosis, the clinician should determine the goals for use.[3] Upright mobility with lower extremity orthoses allows exercise or therapeutic ambulation, household ambulation, or community ambulation. Often an assistive device, such as crutches or a walker, is required. Orthotic and locomotor training considerations will be determined by the strength of key muscles, assessed using the International Standards for Neurological Classification of Spinal Cord Injury (ISNCSCI), and non-key muscles such as hip extensors, knee flexors, and gastrocnemius assessed in traditional manual muscle testing positions. In an adult-based study, individuals with a total lower extremity motor score less than or equal to 20 were found to be limited or household ambulators and those with scores greater than or equal to 30 were found to be community ambulators.[4] The lower extremity motor score is also related to ambulatory ability; the greater the lower extremity motor score, especially in the knee and hip musculature, the greater a person's walking speed and endurance.[5]

The recommendations described in **Tables 1** and **2** are written for persons with complete SCI (American Spinal Injury Association Impairment Scale [AIS] A) and sensory incomplete (AIS B). When considering wheeled mobility, lower extremity orthoses, and/or locomotor training for individuals with motor incomplete SCI (AIS C and AIS D), clinicians need to look at the strength and function of individual lower extremity muscle groups as well as biomechanical alignment, proprioception, and range of motion as opposed to relying on the individual's neurological level. Another important consideration surrounding the orthotic decision and ambulation potential is upper extremity strength and function.

The recommendations for mobility should differentiate between equipment that is medically necessary and equipment that is beneficial. A medically necessary piece of equipment has the capacity to prevent an injury, disease, or symptom from deteriorating, to decrease pain or discomfort, and to improve function.[6] It should be clinically and medically appropriate for the person's diagnosis and be in accordance with accepted standards of practice. It includes the use of wheelchairs and orthoses to provide a means of safe, efficient, and functional mobility. A medically beneficial piece of equipment is defined as equipment that may not be necessary to sustain life or safety but that may prevent degradation of impairment, augment an individual's efficiency and ease of functional skills, decrease caregiver burden, and contribute to health and wellness of those individuals.[6] It includes the use of orthoses for stabilization or therapeutic standing or ambulation, but not for assistance for functional walking/ambulation.[6]

Table 1 describes wheeled mobility recommendations and **Table 2** describes upright mobility recommendations according to neurological level groupings.

Pediatric Considerations and Developmental Aspect

Mobility and development

Mobility enhances how we carry out our daily tasks and affects everything we do. Mobility provides a means to learn, interact with others, attend school, earn a living, and participate in society. With an infant, the ability to move independently facilitates many aspects of development,[7] and early experiences influence all subsequent development. If there is a delay in mobility and motor development, all other development is delayed.

Locomotion induces or accelerates important developmental changes.[8] Independent locomotion is linked to the growth of brain structures, coping, self-awareness, shifts in patterns of attachment and interaction with caregivers, the emergence of a sense of competence and initiative, and the development of cognition.[9] With an infant or toddler, mobility provides a means of exploring the environment. Without independent mobility, a child may have a decreased ability to learn, decreased socialization, and learned helplessness

Table 1. Wheeled mobility recommendations

Neurological level (AIS A and B)	Wheelchair type	Drive control	Seating and seating functions	Seating accessories	Additional accessories	Comments
C1-C4	Power WC base	Dependent on user's abilities and preferences	Solid back support and cushion, power tilt, or power tilt/recline	Head support, pelvic belt, trunk support, and upper and lower extremity supports	Ventilator tray, anti-tippers	• Medically necessary • Front, mid/center, or rear wheel drive • Seating should provide postural support and pressure distribution • Back-up manual WC • Consider user's home and vehicle
C5-C6 Option 1	Power WC base	Typically joystick	Solid back support and cushion,power tilt, or power tilt/recline	Head support, pelvic belt, trunk support, upper and lower extremity supports	Anti-tippers	• Medically necessary • Front, mid/center, or rear wheel drive • Seating should provide postural support and pressure distribution • Back-up manual WC • Consider user's home and vehicle
C5-C6 Option 2 C7-C8 Option 1	Ultra-light, adjustable manual WC frame with push rim–activated power assist wheels or add-on joystick	N/A	Solid back support and cushion	Pelvic belt, trunk support, and lower extremity support	Anti-tippers, hill holders, brake, and extension on wheel locks	• Medically necessary • Ability to independently perform a pressure relief is necessary
C7-C8 Option 2	Ultra-light, adjustable manual WC frame	N/A	Solid back support and cushion	Pelvic belt, trunk support, and lower extremity support	Anti-tippers, hill holders, brake extension projection rims, and wheel locks	• Medically necessary • Ability to independently perform a pressure relief is necessary
T1-S5	Ultra-light, adjustable manual WC frame	N/A	Solid back support and cushion		Anti-tippers and hill holders	• Medically necessary • WC frame may be folding or solid

Note: AIS = American Spinal Injury Association Impairment Scale; WC = wheelchair.

Table 2. Upright mobility recommendations

Neurological level (AIS A and B)	Standing	Ambulation	Comments
C1-C8	Tilt table or standing frame	Not indicated	Medically beneficial Tilt table or standing frame requires appropriate postural supports.
T1-T9	Standing frame	Orthoses (RGOs and HKAFOs) and assistive device	Medically beneficial Ambulation is typically therapeutic distances.
T10-L1	Standing frame	Orthoses (RGOs, HKAFOs, KAFOs) and assistive device	Medically beneficial Ambulation is typically therapeutic or household distances.
L2-S5	Standing frame	Orthoses (KAFOs, AFOs) and often an assistive device FES surface stimulation and often an assistive device Locomotor training	May be medically necessary or beneficial Range of ambulation potential includes functional household to community distances.

Note: AIS = American Spinal Injury Association Impairment Scale; AFOs = ankle-foot orthoses; HKAFOs = hip-knee-ankle-foot orthoses; KAFOs = knee-ankle-foot orthoses; FES = functional electrical stimulation; RGOs = reciprocating gait orthoses.

due to decreased ability to have an impact on the environment. It is critical that we do not wait to see if a child will eventually become an independent ambulator; mobility should be augmented to allow for independence.

RESNA position on the application of power wheelchairs for pediatric users

The Rehabilitation Engineering and Assistive Technology Society of North American (RESNA) published a paper[10] on power mobility in 2009. The position paper describes clinical applications and evidence-based literature supporting the use of power mobility in young children. It is RESNA's position that "age, limited vision or cognition, behavioral issues, and the ability to walk or propel a manual wheelchair short distances should not, in and of themselves, be used as discriminatory factors against power mobility for children." In addition, "RESNA recommends early utilization of power mobility for the appropriate candidates as medically necessary to promote psychosocial development, reduce learned helplessness, and facilitate social and educational integration and independence."

When to begin power mobility training

There is no set age for initiating power mobility training for a child. It has been shown that children 7 to 24 months old can learn to use a powered mobility device safely over short periods of time.[11,12] As opposed to chronological age, cognition and developmental age should be used to guide a clinician on the initiation of powered mobility training. For children without cognitive disabilities, studies have shown that power mobility training can begin within the first year of life.[12] Historically, therapists have considered the use of powered mobility as the ability to independently drive a chair in all situations.[13] Just as a child learns to walk over time, a child should be able to learn to move in a power wheelchair over time. The same principles should be considered for power mobility training as ambulation.[13]

Challenges to pediatric wheelchair configuration

There are many challenges to prescribing a manual wheelchair for a growing child. Regardless of the type of wheelchair frame, the following are recommendations and or considerations for the pediatric population:

1. A solid seating surface through a seat pan or cushion rigidizer is recommended to prevent hip internal rotation and adduction.
2. A solid back provides better postural support.
3. Although air-filled cushions may provide adequate pressure relief, they may impair postural support.
4. The wheelchair frame must allow for growth potential in frame length and width.
5. An adjustable axle is recommended to allow for adjustability in frame height and proper positioning for propulsion.
6. Reverse configuration (having the wheels in front) is an option for very small children, allowing them better access to the wheels.

When prescribing a manual wheelchair, the clinician should consider the wheelchair weight to child weight ratio. It is important to justify the lightest wheelchair possible for the child and to educate parents, aides, and children about avoiding increased weight from bags or backpacks being placed on the back of the wheelchair.

Orthopedic considerations

Orthoses for the lower extremities and the spine are often used to promote normal bone alignment during growth of the hips and spine. Eighty percent to 98% of children who sustain an SCI prior to skeletal maturity develop a scoliosis.[14,15] One study[16] found that 93% of children with SCI who were injured prior to 11 years old and 9% of children who were injured after 11 years old had at least 1 subluxed or dislocated hip. Some treatment methods to address orthopedic issues of the child with SCI may impact the child's mobility. Early bracing of the spine by using an orthosis such as a thoracic lumbar sacral orthosis (TLSO) may delay the age that surgical intervention is required; in curves less than 20°, an orthosis may reduce the possibility of a surgical fusion.[17] In addition, to facilitate proper femoral head and acetabular positioning, an abduction pillow can be used to maintain hip abduction in supine[18] and a pommel can maintain hip abduction while sitting in a wheelchair.

Pediatric progression

When a child sustains an SCI, it is important that ambulation training be supported as an essential component of rehabilitation and that the child's developmental level be taken into consideration.

The "community" that the child will be involved in differs depending on the child's age. For example, the community for infants and toddlers is primarily their home or day care environment. It expands to the playground, neighborhood, and school as the children enter school age and further expands to the community at large for adolescents. Ambulation, therefore, must be part of a program that takes the children's developmental needs into consideration and this program must be flexible, adjusting for their changing needs. Children who are injured younger, especially those injured before 5 years of age, are more likely to ambulate in general and typically ambulate for a longer duration of time than those injured later in childhood.[19-21] Children with paraplegia are more likely to ambulate than those with tetraplegia. For a child to be successful in ambulating, the orthotics need to be as least cumbersome as possible while still supporting the appropriate muscles and joints.

Mobility, and therefore ambulation, must be efficient and facilitate independence. It is a natural for children with SCI to progress to different orthotics, different assistive devices, and ultimately a wheelchair to keep up with peers and be as independent as possible throughout the environment. As children get older, this progression to increased reliance on a wheelchair must be viewed as a natural progression and not as a failure.

Pediatric access to therapy

Physical therapy and occupational therapy are integral components of the rehabilitation of individuals who sustain SCIs. Some children may require the services of speech therapy as well. Access to such therapies may be easier for children to obtain than for adults. This is especially true if the child is injured very early in life, because of the creation of early intervention services. Early intervention is a statewide system mandated by the US Congress in 1986. Each state receives funds from the federal government to run the programs in that particular state. Early intervention is designed to help infants and toddlers from ages 0 to 3 and the caregivers who care for them. After the age of 3 years, children may be eligible to receive services from physical, occupational, and speech therapy through the schools that they attend.

Conclusion

Mobility is critical for proper development to occur in the pediatric population. Making recommendations for mobility is often very challenging for the clinician. It is essential for clinicians providing care to children with SCI to address mobility in a comprehensive and longitudinal manner and across environments.

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