

WHAT DOES THE RESEARCH SAY ABOUT PROVIDING MOBILITY TO YOUNG CHILDREN?

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What we will be covering:

- The Importance of Early Mobility
 - Current research results
 - Please also refer to your handouts



Updated Resource!

- RESNA Position on the Application of Power Mobility Devices for Pediatric Users, 11/2017
- https://www.resna.org/sites/default/files/legacy/Position-Papers/RESNA%20Ped%20Power%20Paper%2010_25_17%20-BOD%20approval%20Nov2_2017.pdf
 - RESNA.org, Knowledge Center



Power Mobility

- What is Power Mobility?
 - Power wheelchairs
 - Battery powered devices
 - Adapted ride-on cars



Self-initiated Mobility

- Self-initiated Mobility
 - The ability to initiate movement independently
 - even if not accurately, efficiently, or functionally
 - Enriched environments and neuroplasticity
 - Includes crawling, scooting, walking, MWC self-propulsion, as well as power mobility



Self-initiated Mobility and Development

- Self-initiated Mobility affects Development
 - Visual, Cognitive, Social, and Perceptual skills
 - Anderson, et al., 2013
 - Bornstein, et al., 2013
 - Social Participation
 - Bray, Noyes, Edwards, & Harris, 2014

Self-initiated Mobility and Development

- Positive impact on:
 - Body functions
 - Sleep/wake cycle
 - Affect and motivation
 - Activity outcomes
 - Self-initiated activity
 - Independent mobility
 - Communication



- Participation outcomes
 - Play skills
 - Social interaction
 - Peer relationships
- Livingstone & Field, 2014

Augmented Mobility Experiences

- Augmented Mobility provides movement to a child for the sake of movement
- Often used with very young children for the developmental, rather than functional, benefit
- Often using adapted ride-on cars



Augmented Mobility Experiences

- Provides a means of exploration and learning to impact overall development
 - Perceptual, cognitive, and social quality of life
- Applies to children who:
 - Need mobility assistance only in early childhood
 - Logan, Huang, Stahlin, & Galloway, 2014
 - Need mobility assistance for life
 - Huang, Ragonesi, Stoner, Peffley, & Galloway, 2014
 - are older, yet functioning at an earlier developmental level, to augment learning and development



What is Effective and Efficient Mobility?

- Time + effort = efficiency
- Safety is also a factor
- Power mobility may provide efficient mobility and save time and effort for other tasks



Environmental Considerations

- Some children will require power mobility due to specific environmental issues
 - Uneven terrain
 - Slopes, ramps
 - Crowds
 - Long distances
- The solution often chosen is dependent manual mobility
 - Rodby-Bousquet, Paleg, Casey, Wizert, & Livingstone, 2016



Environmental Considerations

- Only 10% of children using MWCs outdoors were able to self-propel
- 75% of children using PWCs outdoors were independent
 - Rodby-Bousquet, Paleg, Casey, Wizert, & Livingstone, 2016



Exercise?

- Some team members may hesitate to explore power mobility for a child due to concerns about providing exercise, loss of function, or even weight gain
- Alternative exercise is fine
- Mobility is about efficiency, not exercise
 - Verschuren et al, 2016



Who can benefit from power mobility?

1. Children who will never walk
2. Children with inefficient mobility
3. Children who lose the ability to walk or to walk efficiently
4. Children who need mobility assistance in early childhood

Livingstone & Paleg, 2014 p. 217-218



Children Who Will Never Walk

- Children with:
 - Cerebral palsy at FMFCS level IV and V
 - Spinal muscular atrophy types I and II or congenital muscular dystrophy who lack the muscle strength for ambulation
 - High level spinal cord injuries
 - Osteogenesis imperfecta types II, III, and VIII
 - Arthrogryposis multiplex congenita who are unable to walk or self-propel



Children with inefficient mobility

- A child who may be able to ambulate with or without aids or self-propel a MWC, but inefficiently
- Children with:
 - Cerebral palsy, GMFCS Levels III and IV
 - SCI levels C6 or C7 or thoracic level spina bifida
 - Osteogenesis imperfecta types IV-VII
 - Abnormal muscle tone who lack efficient mobility
 - Juvenile rheumatoid arthritis, cardiac conditions or other medical conditions impacting efficient mobility



Children who lose the ability to walk or walk efficiently

- Acquired conditions leading to a loss of ambulation or efficient ambulation
- Traumatic brain injury (TBI)
- Spinal cord injury (SCI)
- Progressive neuromuscular disease
 - Muscular dystrophy
 - Spinal muscular atrophy, type III
 - Friedreich's ataxia



Children who need mobility assistance in early childhood

- Some children may lag in motor development
- Providing power mobility early and help with overall development until, and if, ambulation develops
 - Cognitive and psycho-social skills (Livingstone & Paleg, 2014)



Will Power Mobility keep my child from walking?

- Such a common question and potential barrier!!!
- Early augmented mobility experiences do not impede development of ambulation
 - Jones, et al, 2012



How Young is Too Young?

- When mobility impairments lead to gaps in participation between a child, their peers, and their family, power mobility should be considered
 - Rosen, L. et al, 2018



How Young is too Young?

- Typically developing infants between 5-10 months successfully used a power mobility device that was operated with whole body movements
 - Larin, Dennis, & Stansfield, 2012
- Infants as young as 11 months, with and without disabilities, initiated movement with a joystick
 - Rogonesi & Galloway, 2012
- 14-30 month olds who had a power mobility device in the home learned successful mobility skills, even with significant disabilities
 - Jones, et al., 2012



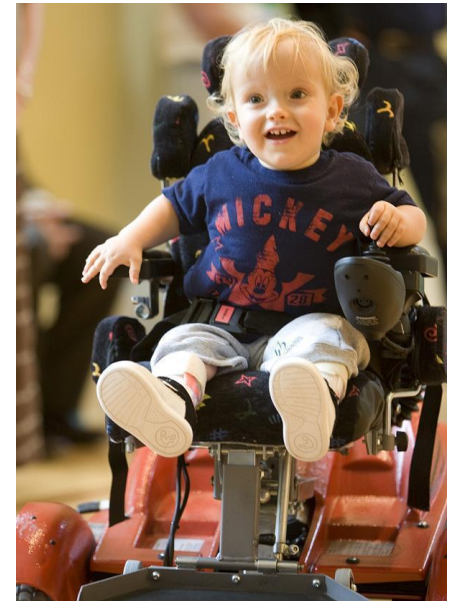
Pre-Mobility Training

- No established training protocols or standardized tests at this time
- Platform trainers can provide mobility experiences, progression of mobility skills, and psycho-social and cognitive development
 - Kenyon, et al., 2015, 2016
- Want more resources?
 - Check out recorded AbleNet webinars on this topic



Learning Curve

- This will vary by individual child, of course
- Children around 24 months of age with physical disabilities can learn to drive competently in about 7.9 months
 - Dunaway, et al., 2013
- Children using alternative driving methods may require more time to learn to drive
- Children with more complex disabilities may require more time, as well
 - Jones, et al., 2012



Learning Stages

- Durkin identified three stages of learning to use a power wheelchair
 - Durkin, 2009
 1. The concept of movement
 2. How to operate a power wheelchair
 3. How to use the wheelchair in daily life



Learning Stages

- Nilsson and Durkin created the Assessment of Learning Power mobility use (ALP)
 - Nilsson & Durkin, 2014
- Provides strategies for training during each stage of learning
- New tool

Challenges

- Challenges limiting power mobility use with children include:
 - Accessibility
 - Funding
 - Perceptions
 - Availability and/or innovation of equipment

Livingstone & Field, 2015



Accessibility

- Power mobility devices are large and heavy
- Home and vehicle accessibility
- Design challenge



Sittin' Pretty in Texas

November 12, 2007

Funding

- Child may be limited to one mobility device
- Age limitations



Perceptions

- Attitudes
 - Professionals, caregivers, funding agencies, physicians
- Delay or absence in consideration of a power mobility device
- Child may be expected to immediately demonstrate competence



Innovation

- Lack of availability
- Loaner and recycling programs are needed
- Need for increased pediatric product options
 - Including low cost and modified toy options
 - Livingston& Paley, 2014



Take Home Message

- Early use of power mobility for children with mobility limitations:
 - Enhances independence
 - Improves development in multiple areas
 - Enables children to grow to become productive and integrated members of society

Questions?

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Thanks!

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RESNA Position on the Application of
Power Mobility Devices for Pediatric Users-Update 2017

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**RESNA Position on the Application of
Power Mobility Devices for Pediatric Users**

About This Paper

This is an official RESNA Position Paper on Clinical and Professional Practice. As such, it has been prepared in accordance with the specific guidelines and approval process defined by the RESNA Board of Directors for Position Papers. See

<http://www.resna.org/knowledge-center/position-papers-white-papers-and-provision-guides> for a complete description of this procedure. Key aspects of this procedure include:

1. Establishment of a Working Group of three or more experts to author the paper, using evidence from the published literature, documented best practices, and other input from experts in the field as the basis for the content.
2. Circulation of the draft to RESNA members and others for a 30-day public comment period, and subsequent revisions.
3. Review of the revised draft by the RESNA Board of Directors, and subsequent revisions.
4. Final approval of the paper by the RESNA Board of Directors.

This paper is valid for five years from the final approval date. It may be revised over time to ensure that its information remains current.

Final approval date: November 2, 2017

The purpose of this document is to share typical clinical applications as well as to provide evidence from the literature supporting the application of power mobility (PM) for young children and to assist practitioners in decision-making and justification. The beneficial effects of power mobility for children have been reported as a clinical consensus statement (Rosen et al., 2009). The purpose of this manuscript is to update this RESNA Position on the Application of Power Wheelchairs for Pediatric Users with more current and additional scientific literature.

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 providing PM for children. RESNA recommends early utilization of PM for children with mobility limitations as medically necessary, to promote integration and psycho-social development, reduce passive dependency, and to enhance participation, function, and independence.

This paper is not intended to replace clinical judgment related to specific client needs.

According to the World Health Organization (WHO, 2011), 15.3% of the world's population has a moderate to severe disability, 93 million of whom are children. This equates to 5.1% of all children ages 0-14 years having a moderate to severe disability. In the United States, 145,000 of children under the age of 18 years use some form of mobility device to augment or ameliorate a mobility deficit (Kaye, Kang, & LaPlante,

2000). The development of independence and participation in social, educational and cognitive environments is directly related to the child's capacity to meet changing and developing mobility demands (Anderson et al., 2013).

Mobility facilitates environmental exploration and leads to development and maturation. A comprehensive review of the role of locomotion (Campos et al., 2000), suggests that there is a relationship between self-produced mobility and the development of social interaction, visual perceptual skills, visual abilities and communication. Early mobility experience has also been shown to affect academic achievement and intellectual functioning later in life (Bornstein, Hahn, & Suwalsky, 2013).

A lack of mobility impairs the child's ability to engage in play behaviors, which can be detrimental to development. Psychological development of the child depends primarily on play, and contributes to emotional and social skills (Gray, 2011). Meaningful participation in age-appropriate activities may be achieved through a variety of different mobility methods and assistive technologies depending on the environment or the activity (Wiat & Darrah, 2002). Power mobility (PM) is an effective means of providing efficient self-produced mobility for children with mobility limitations.

What is Power Mobility?

PM includes power wheelchairs but also other types of battery powered devices used by children for mobility experience. These include those specifically adapted for children with special needs such as adapted ride-on-toy cars, scooter boards or standers, as well as custom switch adaptations to commercially available powered ride-on-toys. The term power mobility device (PMD) encompasses power wheelchairs and other powered devices such as those described above.

How does self-initiated mobility affect development?

There is a strong correlation between self-initiated mobility and overall development. Mobility is associated with the development and acquisition of important visual, cognitive, social and perceptual skills (Anderson et al., 2013; Bornstein et al., 2013; Knudsen, 2004). PM has also been shown to impact cognitive and language development (Jones, McEwen, & Neas, 2012; Lynch, Ryu, Agrawal, & Galloway, 2009), social participation (Bray, Noyes, Edwards, & Harris, 2014), and ultimately independence (Bottos, Bolcati, Sciuto, Ruggeri, & Feliciangeli, 2001; Deitz, Swinth, & White, 2002).

The strongest research evidence for children with mobility limitations supports the impact of PM on overall development and independent mobility (Jones et al., 2012). Most research evidence supporting use of PM with children is descriptive but suggests a positive impact on body functions such as sleep/wake cycle, affect and motivation; activity outcomes such as self-initiated activity, independent mobility and communication; as well as participation outcomes such as play skills, social interaction and peer relationships (Livingstone & Field, 2014).

What are augmented mobility experiences?

Augmented mobility experiences (i.e. using a joystick or switch to move a ride-on toy), are being introduced at very young ages and provide a means for exploration and learning which may affect later perceptual, cognitive and social quality of life outcomes (Galloway, Ryu, & Agrawal, 2008; Lynch et al., 2009). This applies both to children who need mobility assistance only in early childhood (Logan, Huang, Stahlin, & Galloway, 2014), as well as children who will need assistance throughout their lifetime (never walk) (Huang, Ragonesi, Stoner, Peffley, & Galloway, 2014).

PM experience can also augment learning and development for older children functioning at early developmental levels. Smart wheelchairs (PMD's with additional line following sensors, collision sensors or voice feedback capabilities) may be used to develop PM skills. Some children with complex disabilities have been able to transition from these to standard power wheelchairs (Nisbet, 2002). Others have used specialized PMD's and Smart wheelchairs to develop early mobility skills such as switch access and ability to attend to direction of travel (Kenyon et al., 2016; Kenyon, Farris, Brockway, Hannum, & Proctor, 2015; McGarry, Moir, & Girdler, 2012).

What is effective and efficient mobility?

Time and energy efficient, functional mobility is essential for children's learning, development and participation. Children with disabilities need to be able to maintain pace with peers and explore their environment freely. This focus on effective mobility rather than normalization of motor development and movement patterns represents a paradigm shift in pediatric rehabilitation philosophy (Wiat & Darrah, 2002). PM may augment a child's other mobility methods, allowing them to keep up with their peers in certain activities and environments.

For children with disabilities gait is often more inefficient than their age-matched peers (Piccinini et al., 2007). Low aerobic capacity and abnormal gait patterns limit cadence, create larger fluctuations in center of mass excursion and increase metabolic cost in children with cerebral palsy (CP) (Dallmeijer & Brehm, 2011; Kamp et al., 2014). Independent ambulators with spina bifida have decreased muscle strength, lower levels of physical activity, and increased oxygen cost with walking (De Groot, Takken, Schoenmakers, Vanhees, & Helders, 2008; Schoenmakers et al., 2009). Power wheelchairs can be an effective way to provide efficient independent mobility in these populations.

What is the effect of the environment on mobility?

Environmental factors such as the presence of crowds or uneven terrain creates the potential for balance loss leading to use of alternative forms of mobility to prevent falls. Longer distances have greater endurance and cadence requirements for success. Unfortunately, the solutions are often dependent forms of mobility such as adaptive strollers or manual wheelchairs pushed by caregivers (Palisano et al., 2003; Rodby-Bousquet & Hägglund, 2010)(Rodby-Bousquet, Paleg, Casey, Wizert, & Livingstone, 2016). PM may be an alternative to augment ambulatory children's mobility in a more independent manner than resorting to passive transport.

Many children with CP may walk or crawl in the home environment but require a mobility device for public spaces (Palisano et al., 2003; Tieman, Palisano, Gracely, & Rosenbaum, 2004; Tieman, Palisano, Gracely, & Rosenbaum, 2007). Choice of mobility method is influenced by level of motor function as well as environmental factors and may change over time as children get older and transition from elementary to middle or secondary school where they need to travel greater distances (Kerr, McDowell, Parkes, Stevenson, & Cosgrove, 2011). Adolescents with CP have described safety and efficiency as being the most important factors influencing their choice between different mobility methods to facilitate social and community engagement and increase participation (Palisano et al., 2009). PM may maintain a child's mobility across multiple environments despite changing abilities.

Approximately 60% of individuals with spina bifida use wheeled mobility outdoors (Johnson, Dudgeon, Kuehn, & Walker, 2007) with two thirds using manual wheelchairs and one third using power wheelchairs (Dicianno, Gaines, Collins, & Lee, 2009). In a total population of children with CP in one region of Sweden (Rodby-Bousquet & Hägglund, 2010), 40% used wheeled mobility outdoors with 62% of these being pushed by adults, 6% self-propelling a manual wheelchair, and 15% using power mobility. From the group of children who had some ability to walk outdoors without aids, Gross Motor Function Classification System (GMFCS) II (Palisano et al., 1997), 39% used wheelchairs outdoors, but 30% were dependent on adult assistance when in a manual chair. These results were confirmed in their more recent study (Rodby-Bousquet et al., 2016) where only 10% of children using manual wheelchairs outdoors were able to self-propel while 75% of those using PM were independent. PM can provide consistent independence across environments for children who are dependent in certain situations.

Should mobility have a component of exercise?

For mobility to be functional it must be efficient, and should not be confused with exercise. Children with disabilities, just like their peers, need cardiovascular exercise and may also benefit from strength training. Effective means of exercise for non-ambulatory children include assisted bicycle training (Jansen, van Alfen, Geurts, & de Groot, 2013), treadmill training (Oliveira, Jácome, & Marques, 2014), aquatics (Anziska & Sternberg, 2013) and specific muscle strengthening (Anziska & Sternberg, 2013; Cup et al., 2007; Oliveira et al., 2014). Technology such as video game-cycles may provide effective exercise for adolescents with Spinal Cord Injury (SCI) (Widman, McDonald, & Abresch, 2006) and playing power soccer may trigger cardiovascular responses in children with neuromuscular disease in a similar manner to vigorous exercise in typical populations (Barfield, Malone, Collins, & Ruble, 2005).

Exercise by definition is tiring, which is the reason the general population does not use their everyday mobility as such. Children with disabilities should be using efficient means of mobility, maintaining a similar speed to their peers without undue effort or fatigue. Evidence supports that mobility methods with a high energy cost can have a negative effect on learning and school performance (Franks, Palisano, & Darbee, 1991). Concerns about weight gain and loss of function must be addressed as a means of overall health and fitness and not as an alternative to adequate and efficient navigation within one's environment (Verschuren et al, 2016).

Who can benefit from power mobility in the pediatric population?

Hays (1987) originally proposed the concept of four different groups of children who could benefit from PM. These groups were developed and defined through an expert consensus process that included an international panel of 16 expert clinicians and researchers: 1. Children who will never walk, 2. Children with inefficient mobility, 3. Children who lose the ability to walk or to walk efficiently, 4. Children who need mobility assistance in early childhood (Livingstone & Paleg, 2014 p217-218). The following text describing the four groups is adapted with permission from the article: Livingstone R and Paleg G. Practice considerations for the introduction and use of power mobility for children. *Dev Med Child Neurol* 2014; **56**: 210-221, which has been published in final form at <http://onlinelibrary.wiley.com/doi/10.1111/dmcn.12245/pdf>

Children who will never walk. There are several conditions where children will never walk and cannot use a manual wheelchair effectively. PM is required for independent, efficient or functional mobility in the following populations. These diagnoses listed are the most common conditions, however there are children with other genetic or metabolic diagnoses that will also fall in these categories: (1) Children with CP functioning at GMFCS Levels IV and V who do not have the motor skills to walk or propel a manual wheelchair; (2) Children with spinal muscular atrophy types I and II or congenital muscular dystrophy who lack the muscle strength necessary for walking; (3) Children with high-level spinal cord injuries who are unable to walk or use a manual wheelchair due to paralysis; (4) Children born with osteogenesis imperfecta types II, III, and VIII who do not have the ability to walk or self-propel due to multiple bony fractures, leading to loss of range, orthopedic distortions, muscle atrophy around affected bones and high risk of further fractures; (5) Children born with arthrogyrosis multiplex congenita (AMC) who may also be unable to walk or self-propel, dependent upon which joints are fused and muscle atrophy.

Children with inefficient mobility. Some children are able to ambulate with or without aids, or self-propel a manual wheelchair, but inefficiently. This might include the following populations: (1) Children with CP, GMFCS Levels III and IV, who lack the motor skills to ambulate or self-propel a manual wheelchair efficiently (Rodby-Bousquet & Hägglund, 2010); (2) Children with SCI at levels C6 or C7 or thoracic level myelomeningocele (spina bifida) who are inefficient in non-powered mobility devices due to paralysis and muscle weakness; (3) Children with osteogenesis imperfecta, types IV-VII who do not have the ability to use non-powered mobility options due to range of motion loss, joint changes and muscle weakness; (4) Children with abnormal muscle tone (i.e. certain metabolic conditions) who also lack efficient mobility; (5) Finally, children with juvenile rheumatoid arthritis, cardiac conditions and other medical conditions who have inefficient mobility at times, depending upon the course of their condition and treatment.

Children who lose the ability to walk or to walk efficiently. Some children have an acquired condition that leads to a loss of ambulation or efficient ambulation. These acquired conditions include traumatic brain injuries (TBI) and SCI.

If a child has a progressive neuromuscular disease and ambulatory mobility is lost, PM will usually be required. Some of these conditions include muscular dystrophy, spinal muscular atrophy (type III) and Friedreich's ataxia. As the condition continues to progress, alternative access methods, power seating and the need to accommodate medical equipment must be considered (Richardson & Frank, 2009).

Secondary impairments from aging are an important and often overlooked factor in the treatment of children with disabilities. There is a high incidence of pain and chronic fatigue impacting physical function in adulthood (Malone & Vogtle, 2010). Some experience physical decline starting in the adolescent or early adult years. PM may enhance safety, efficiency and independence in community mobility for children with a variety of disabilities. This may provide opportunity for efficient function with less joint compromise, pain, and energy cost. PM may also assist in the preservation of life long activity levels and functional participation in self-care and community life.

Children who need mobility assistance in early childhood. Children with a variety of developmental disabilities and other diseases may lag in motor development. These children may gain the ability to ambulate or use non-powered mobility devices as they grow, develop and undergo therapy and other medical interventions. However, even if future ambulation or non-powered mobility device use is anticipated, it is critical to provide PM at the age their peers are starting to ambulate to develop the cognitive and psycho-social skills typically associated with the onset of mobility (Livingstone & Paleg, 2014; Lynch et al., 2009). Research shows that these early augmented mobility experiences do not impede development of ambulation (Bottos et al., 2001; Jones et al., 2012).

When should children start using power mobility?

Timing should be related to a child's inability or decreased ability for functional, independent mobility. Children develop autonomy and integration into society through participation with others and this should be a primary aim of pediatric rehabilitation (Shikako-Thomas et al., 2012). When mobility impairments lead to gaps in participation between a child, their peers, and their family, PM should be considered.

In typical development, a baby's movement and subsequent mobility create opportunities for interaction and participation. These interactions provide socialization as well as object exploration and choice making. Active participation in mobility positively affects the frequency of engagement with objects as well as frequency of caregiver interactions which can in turn impact cognition (Lobo, Harbourne, Dusing, & McCoy, 2013). While recognizing that there are many aspects to cognition, motor and cognitive development are closely intertwined in young children and differentiating these is beyond the scope of this paper.

In early childhood, immobility limits socialization and opportunities for play, which decreases inclusion and promotes more solitary behaviors. PM has been shown to positively impact level of play in children ages 18 months to 6 years (Guerette, Furumasu, & Tefft, 2013). Children who are able to drive competently, use PM for a variety of functional activities such as attending school, socializing with friends, community outings and participating in sports such as power soccer (Evans, Neophytou, De Souza, & Frank, 2007). The ability to independently mobilize is critical in defining social relationships as well as participation in the classroom.

During adolescence, young adults begin to enter the workforce and further expand their social and academic roles leading up to a fully independent lifestyle. Reliance on adult or caregiver assistance for mobility is a direct barrier to participation in these environments. Few of the currently available participation outcome measures are specific for use with children using PM (Field, Miller, Ryan, Jarus, & Abundo, 2015). This is an area of research currently under development (Field, Miller, Jarus, Ryan, & Roxborough, 2015; Field, Miller, Ryan, Jarus, & Roxborough, 2015).

Introduction of PM for some therapists focuses on arbitrary age-based criteria while others look to a set of similarly arbitrary skills that indicate readiness. Researchers have been exploring how young children can begin using PM. Typically developing infants aged between 5 and 10 months have been successful using a PMD that utilized whole body movement rather than a joystick (Larin, Dennis, & Stansfield, 2012). Researchers at University of Delaware have had success with infants with and without disabilities initiating movement using joysticks at 7 months (Lynch et al., 2009), 11 months (Ragonesi & Galloway, 2012) and 14 months-of-age (Galloway et al., 2008). Case studies describe children with age-appropriate cognitive skills using PM competently as young as 17 months (Zazula & Foulds, 1983), 20 months (Jones, McEwen, & Hansen, 2003), and 22 months-of-age (Everard, 1984). Jones et al (2012) showed that 14-30 month olds who had frequent access to a PMD in the home setting learned successful mobility skills in the presence of significant disability.

Nilsson explored power wheelchair training with adults and children with profound cognitive disabilities. Her work correlates ability to acquire joystick driving skills with a higher number of training sessions, rather than factors such as age, visual and physical abilities (Nilsson, Nyberg, & Eklund, 2010). Thus, frequency and opportunity for PM experience may be more important in development of PM skills (Bottos et al., 2001).

This approach is consistent with typical development as mobility skills are not suddenly present but rather emerge during a prolonged learning period and with high variability. Skills such as crawling, rolling, and walking are obtained over months with preparatory activities involving frequent failures and falls. For example, ambulatory infants 12-19 months of age fall at a rate of 17 times per hour and tend to move in bursts contrasted with prolonged periods without movement (Adolph et al., 2012). This trial and error is mandatory for successful emergence of the skill of ambulation as infants learn to navigate natural environments. Similar developmental considerations need to be a component of emergent mobility skills in powered devices. Mobility training is discussed in more detail below.

Typically developing children participate in mobility-based activities without intelligence criteria. IQ does not appear to correlate with ability to drive a power wheelchair as children with moderate and severe intellectual disability have demonstrated the ability to learn to use a power wheelchair competently (Bottos et al., 2001).

How should children learn to use power mobility?

A frequently asked question is how to teach children to operate power wheelchairs. No established training protocols or standardized tests are commonly used when training children to operate power wheelchairs. Using a power wheelchair includes understanding mobility concepts (i.e. directional concepts), controlling an input method (i.e. switches or joystick) and combining this with the dynamic experience of moving (vision and vestibular). Although positioning and postural support are not the focus of this paper, it is essential to ensure that the child is well supported with an appropriate individualized seating system prior to beginning power mobility assessment and training.

It is critical to determine the optimal driving method (input device) for the child and postural supports should be optimized to enable efficient and effective use of this driving method over time. Learning will not be optimal or even possible with a driving method the child is unable to efficiently, effectively and consistently operate. A variety of alternative input methods are available to match a child's abilities. The inability to use a joystick should not limit access to power mobility. The driving method should be monitored and changed over time to match the child's abilities as they grow and develop. Children with progressive conditions may require an alternative access method to compensate for increased muscle weakness. In contrast, access may also change as children gain motor control due to maturation or therapeutic and medical interventions.

Training strategies

A variety of different training strategies have been described in the literature; some focus on use of additional technologies, while others focus on the interactions between the adult, the child and learning environment (Livingstone, 2010).

Researchers have used different types of robotic systems when training children to use PMD's (Larin et al., 2012; Secoli, Zondervan, & Reinkensmeyer, 2012). Some PMD's allow the researcher to assist the child via remote controls (Galloway et al., 2008; Lynch et al., 2009). Other systems directly correct the user's movements through the joystick to refine wheelchair operation and control (Marchal-Crespo, Furumasa, & Reinkensmeyer, 2010).

Some Smart Wheelchairs prevent children from hitting obstacles and may have line-following capabilities (McGarry et al., 2012). However, limiting the child's control may impair learning, particularly if the child has never moved independently. The child may not be able to distinguish between their own actions and the corresponding effects versus the actions of the robotic base or others (Nilsson & Durkin, 2014).

Virtual reality systems have also been used to train children to operate power wheelchairs (Adelola, Cox, & Rahman, 2009). However, this approach may be less effective than

training in a PMD for young children, and those with complex disabilities (Nilsson & Nyberg, 1999). Platform trainers (where a child sits in their own manual wheelchair on a powered base) may provide independent mobility experiences for children who might otherwise not have been considered for a power wheelchair (Kenyon et al., 2015). Toddler platform trainers have also been used with car seat positioning to allow PM experiences for younger children (Kenyon et al., 2016). Children have demonstrated progression of PM skills and positive psycho-social and cognitive change through these training experiences.

In most clinics and facilities, however, obtaining robotic, virtual reality or other specialty training systems is not feasible due to the cost and complexity of these technologies. It is important to understand that children at all levels can benefit from and develop independent mobility without these specialty devices and with little focused training (Jones et al., 2012).

Jones et al (2012) found that by placing power wheelchairs in the homes of children with profound disabilities and allowing their families to practice with the devices, many of the children gained independence. These children used both joysticks and other specialty controls for their wheelchairs. Many of the children met most thresholds for prescription of a wheelchair in less time than children without a power wheelchair with which to practice.

How quickly do children learn to use power wheelchairs?

The earliest group studies (Butler, Okamoto, & McKay, 1983, 1984) suggest that children as young as 24 months with physical disabilities can learn to drive competently in less than seven weeks. A more recent group study (Dunaway et al., 2013) reports a longer period of time (7.9 months) for a similar population. The study concluded that this longer time period was due to one child who was unable to use a standard joystick and required access modifications.

In other reports, children who use alternate access methods to the joystick appear to require longer periods of time to learn to drive (Huhn, Guarrera-Bowlby, & Deutsch, 2007). Children with more complex disabilities such as CP that may also impact cognitive, sensory and communication skills appear to require a longer period of time to learn driving skills (Bottos et al., 2001; Jones et al., 2012).

Stages of learning

Subjects in the Driving To Learn study attended multiple training sessions (Nilsson et al., 2011). A variety of training techniques, commonly used in most wheelchair clinics, were used. The study identified eight stages of learning to operate a power wheelchair, ranging from accidentally triggering a joystick to using the wheelchair to complete functional activities. The experience of self generated mobility led to increased function in all participants whether or not they achieved independent joystick operation.

From observation of 22 children with and without disabilities, Durkin identified three stages of development in learning to use a power wheelchair (Durkin, 2009). First,

children learned the concept of movement, then how to operate the power wheelchair and finally, how to use the wheelchair in daily life.

Nilsson and Durkin combined their research to create the Assessment of Learning Powered mobility use (ALP) (Nilsson & Durkin, 2014). The tool is similar to Nilsson's previous tool with eight stages of learning (Nilsson, Eklund, & Nyberg, 2011), but also provides strategies for working with a child during each stage of learning to best facilitate function. These strategies are available as an addendum to their research and can help to guide training for this population. As the tool is new, it has not gained widespread acceptance at this time, but does contain helpful information.

Mobility training guidelines

Mobility training can be used to develop readiness or optimize use of a PMD. Before beginning mobility training, consider expectations, driving method and wheelchair programming. The mobility experience, rather than age, of a child will determine expectations. A 16-year-old, with no experience of independent movement, will likely function at the same level as a 2-year-old who is experiencing independent movement for the first time.

A joystick can be an abstract concept for some children, providing movement in 360 degrees and increased speed when deflected from center. Switches each represent a discrete direction, such as Forward, Left or Right. Some children learn more easily using switches while for other children, learning with a joystick is more intuitive, as the user simply points the handle where they wish to move. Switch head controls are helpful for children who have limited hand function and may also be quite intuitive as the child holds their head up to go forward and looks in the direction they wish to turn. Again, a wide variety of driving methods are available to best meet an individual's needs. Many types of switches can be used at a variety of body sites.

It is critical to program the wheelchair to be responsive to the child's movements without being too jarring or eliciting a startle response. If the chair responds too quickly, it may startle the child. If it responds too slowly, the child may not develop the cause and effect of moving the joystick or triggering a switch.

Training children in quiet and familiar environments is commonly recommended. This lessens distractions and allows the child to focus on the task. Similarly, limiting verbal directions as the child accommodates to the device allows the child to experience motion and learn to move the device.

When learning to use a power wheelchair, allowing children to bump into objects helps to develop depth perception and judgment. Reducing speed and force through programming (i.e. torque or power), will eliminate or reduce damage caused by these "bumps." Therapy bolsters or balls can be used as obstacles.

The length of training sessions vary based on a child's needs and function. It is important to assess the child's fatigue and frustration level and stop the session before either is too high. Care should be taken to prevent the child from seeing the device as a frustrating

item. Sessions as short as 15 minutes, or as long as two hours may be appropriate based on a child's needs.

Challenges in using power mobility with children

A number of challenges or barriers limit PM use with children. These include accessibility, funding, perceptions, and the availability of innovative devices (Livingstone & Field, 2015).

Commercially available power mobility devices, even those marketed for very young children, are typically large and heavy requiring costly lifestyle accommodations to create accessibility for use. Industry innovation is greatly needed for small, lightweight, child and family friendly PMD's that are suitable for use in the multiple environments and can be transported in a typical vehicle (Feldner, Logan, & Galloway, 2016). Even when the primary home is made accessible, children are still restricted from using their devices in the homes of friends and extended family members as well as many places in the community. Furthermore, transportation of these devices is complex, limited or often not available. Product development can increase powered mobility utilization by transcending these architectural and transportation barriers inherent with today's designs.

Funding challenges create frequently encountered barriers. Insurance policies often limit children to one primary mobility device. Children often require different mobility devices for maximal independence in the variety of environments encountered in daily life. Limitations based on DME policy exclude the many children who require a combination of manual, power and ambulatory technologies from full participation. Other policies set restrictive guidelines based on age or have extensive timelines for approval. Re-evaluation of funding policies is critical to support rather than inhibit development.

In addition, the attitudes of professionals and caregivers such as funding and insurance agencies, therapists, doctors and parents also has an influence on children's ability to access and use PM (Livingstone & Field, 2015). For many immobile children, there is a substantial delay or absence in the consideration of powered mobility. Other children are expected to immediately demonstrate competence in a device or meet qualification criteria without sufficient opportunities for mobility experience or customization of access to meet their needs. Better consensus in the medical and funding communities is necessary to support the developmental process of learning power mobility in addition to inclusion of powered mobility as part of a range of options routinely presented to parents.

Finally, a major limitation is the lack of availability of the equipment necessary to build the experience needed for mobility skill development. The development of loaner and recycle programs can support this need. These programs require resources for staffing and space in addition to equipment maintenance and are not found frequently in the United States. In addition, manufacturers need to increase the range of options of devices available for the pediatric population. These should include low-cost and modified toy options for children who may only use PM for short periods in early childhood, as well as those who may progress to using a power wheelchair as their main mobility device in the future (Livingstone & Paleg, 2014).

SUMMARY

It is RESNA's position that early utilization of PM for children with mobility limitations enhances independence, improves development in multiple areas, and enables children to grow to become productive and integrated members of society. Ideally, mobility should be effortless and provide children with the opportunity to attend to and fulfill all daily tasks as typically expected from their non-disabled peers. Age, limited vision or cognitive deficits, difficulty accessing controls, parental concerns, and the ability to utilize other means of mobility for very short distances should not, in and of themselves, eliminate the child as a candidate for PM.

Without efficient, independent mobility, children may develop passive behavior and experience delays in both physical and cognitive domains. As discussed above, new child and family friendly PM technologies are needed to augment mobility for children of all abilities.

Further research is needed to continue to support optimal power mobility assessment, training and benefits.

Case Studies

Case 1. Max is a four-year-old boy diagnosed with CP. He is described as GMFCS Level V as he is able to sit in a supportive custom seating system with head support. Max has limited hand use and has most success using switches positioned by his head. He is able to communicate some basic choices using switches, body language, facial expressions and eye gaze. When he was 18 months old, he began using a switch adapted ride-on toy car with a supportive seating system. The switch was mounted on a flexible mount behind his head to encourage lifting his head to make the toy go. During the 6-month loan period with the ride-on toy, Max developed his ability to consistently use the switch, to balance his head and to look in the direction of travel. With the assistance of a therapist, his family borrowed a used wheelchair with supportive seating and a digital (switch) interface so additional switches for turning could be introduced. Over the following year Max learned to start and stop with the switch behind his head and to steer the wheelchair towards different targets using switches mounted by his left and right temples. He recently received his own power wheelchair with tilt-in-space and a proximity head array.

Case 2. Lindsey is a 12-month old girl diagnosed with Myotubular Myopathy. She is ventilator dependent and has poor trunk and head control and limited upper extremity strength. She is a bright young lady with no cognitive limitations. A trial operating a power wheelchair using a switch tray revealed that this was her best driving method. With the wheelchair not fully adjusted to fit her, she can operate the switch tray with minimal assistance and cuing. A home trial confirmed that she will benefit from the device and her family is prepared to properly supervise her. After almost a year of submissions and appeals, Lindsey received her power wheelchair. Now that she has a properly sized and fitted wheelchair she is able to operate the wheelchair with supervision and occasional assistance. Since receiving the wheelchair, she is now signing and pointing to express her needs.

Case 3. Peter is a three-year-old boy with diplegic cerebral palsy. He simultaneously began power wheelchair trials and supported play in a switch adapted ride-on car. He initially accessed the power chair utilizing mechanical switches on a tray as a joystick provided more degrees of movement than he could manage. After multiple sessions working with switches, he was able to transition to a pediatric joystick mounted in midline. Multiple programming drives provided his family several learning modes. Movement in all 4 directions was an option in one mode, the second mode allowed only turns and a third mode provided only forward and reverse. This allowed Peter the opportunity to have success in hallways and access open environments more independently. In therapy, Peter works on improving his gait with a reverse Kaye walker and has learned to crawl at home. Peter received his power wheelchair about 4 months ago. With a strong team approach, the chair has been integrated as a mode of mobility in school, community and home environments. Access to multiple modes of augmented mobility in all environments allows Peter to maximize his participation at all levels and declare his own independent ideas in everyday situations.

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