

Practice considerations for use and introduction of power mobility with children

This is the accepted version of the following 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>

Roslyn Livingstone MSc(RS), OT
Occupational Therapist
Sunny Hill Health Centre for Children
Vancouver, BC, Canada

Ginny Paleg DSc PT, MPT, PT
Physical Therapist
Montgomery County Infants and Toddlers Program
MD, USA

Word Count: 7,093

Corresponding author:
Roslyn Livingstone
Therapy Department
Sunny Hill Health Centre for Children
3644 Slocan St
Vancouver
BC
V5M 3E8
Canada
Email: rlivingstone@cw.bc.ca
Fax #: 604 453 8309

Abstract

Aim: To support clinicians in recommending and justifying power mobility for children with different ages, needs and abilities. This paper includes three distinct sections: literature review; Delphi consensus; and clinical practice considerations.

Methods: A scoping review of eight electronic databases and manual searches to February 2011 formed the basis for a draft paper including 15 themes or transferable messages from 27 articles meeting initial inclusion criteria. Informal consensus at two international conference presentations refined and modified the paper to include ten messages supported by 24 articles. The literature review was updated May 2012 and a modified Delphi process sought to formalize the consensus process with an international panel of 16 expert clinicians and researchers using *a priori* criteria of 80% agreement.

Results: Evidence was level IV or V except one level II and one level III study. Expert consensus on the content and wording of nine transferable messages may raise evidence overall to level III.

Interpretation: This paper suggests that power mobility may reasonably be considered as an effective and appropriate intervention for: children lacking efficient, independent mobility from around 12 months of age; children who may never become competent drivers; or children lacking independent mobility only in early childhood.

What this paper adds:

- First international consensus on power mobility combining research evidence with expert opinion.
- Synthesizes evidence providing clinical practice suggestions for using power mobility with children of different ages, needs and abilities
- Includes children who may never become competent drivers or who need mobility assistance only in early childhood.

The onset of crawling has a broad effect on children's overall development.^{1,2} Using a power mobility device has been shown to trigger emotional and visual-perceptual development in a similar manner.³ Children typically take independent steps and freely explore their environment by 12-15 months of age whereas children with physical disabilities may have limited opportunities to learn about the properties and principles of their own bodies in space. Lack of purposeful movement and a limited ability to affect the environment can result in passive, dependent behaviour.⁴ Power mobility allows children with physical disabilities to move around more effectively and efficiently in their environment. Children may also use other mobility aids, such as walkers and manual wheelchairs, but these are only considered functional mobility aids if the child is able to keep up and participate with their peers.

Despite a developing body of research evidence, power mobility continues to be underutilized even though it is the most effective means of providing independent mobility to children with severe physical disabilities.⁵ Although clinicians may be motivated to incorporate research evidence into their practice they often do not have the time or skills to evaluate the available research. Systematic reviews can be an effective means of identifying the best research evidence, but clinical practice guidelines may be more helpful for integration into clinical practice.⁶

In 2010, the authors were invited to participate in a best-practice workshop on use of power mobility with children at the International Interdisciplinary Conference on Posture and Wheeled Mobility in Glasgow, Scotland. At that conference, current published opinion on the topic was discussed and workshop participants recommended development of a paper that would support clinical practice and clarify ‘appropriateness’ for power mobility. Specific recommendations included an up-to-date literature review with levels of evidence and inclusion of the child and family perspective.

Part I: LITERATURE REVIEW AND PAPER DEVELOPMENT METHODS

Since a standard systematic review protocol would be too restrictive a method to address the broad range of concerns and perspectives to be included in this paper, a scoping methodology was used.⁷ An electronic search of the following databases was completed in February 2011 and updated May 2012: OT Seeker; Physiotherapy Evidence Database (PEDro); EBM Reviews; CINAHL; Medline; EMBASE; PsycInfo; and ERIC. Key terms included: power(ed) mobility, power(ed) wheelchair, child(ren) and relevant medical subject headings for each database such as wheelchair/powered. Reference lists of articles were reviewed to identify additional studies, a hand search was undertaken to find known studies, and known researchers were contacted to identify or clarify detail on unpublished studies.

English language studies were included if they involved at least one child with a disability below the age of 19 years and addressed the use of a power mobility device with regard to: age of introduction; impact on development; and influences on successful use. Power mobility device included power wheelchairs, powered ride-on toys or cars, powered scooter-boards or powered standers. All types of studies were included from randomized controlled trials (RCT’s) to single case studies. Qualitative or mixed methods designs were also included to ensure representation of the child and family perspective. No restrictions were placed on date of publication or publication status as some important early research studies were known to have been published in conference proceedings or reports.

Titles and abstracts were read for all 107 articles or reports that met our initial wide-ranging criteria. Over 90% of these articles were also read in their full-text version. Descriptive or magazine articles, non-systematic review articles, or those that had a technology or equipment development focus were excluded. Surveys or cross-sectional designs were included if they addressed the child and family perspective or outcomes related to the child’s use of power mobility. Those surveys reviewing service provision or provider perspectives were excluded.

Appraisal of initially included studies was completed using standard data extraction forms for quantitative⁸ and qualitative⁹ designs. The research on knowledge transfer suggests that take-home, or actionable, messages should be transferred from a body of research knowledge rather than from single studies and are referred to as transferable messages.¹⁰ Some transferable messages had been previously identified by the first author¹¹ and discussed at conference presentations. Both authors then agreed on transferable messages or themes emerging from the literature review. Studies that provided strongest support for these messages became the 27 initially included articles. Additional case-study, cross-sectional and qualitative studies were identified, but were

not included as they did not add to level of evidence, increase applicability of the transferable messages or support additional messages.¹²⁻²⁰

The American Academy of Cerebral Palsy and Developmental Medicine (AAPDM) guidelines (Appendix 1) were used to determine levels of evidence for included studies, including group and single-subject designs.²¹ Two reviewers independently determined evidence levels; where differences occurred, they discussed scores until consensus was reached. Their consensus scores are reported throughout. The AAPDM systematic review protocol was not followed as it was developed for narrower intervention questions and quantitative studies only.

In order to address the original direction recommended by participants at the best practice workshop in Glasgow, a draft paper was developed structured around four groups of children identified in the literature as being ‘appropriate’ for power mobility: children who will never walk; children with inefficient mobility, children who lose the ability to walk or to walk efficiently; and children who need mobility assistance in early childhood.²² Two additional sections: learning power mobility skills; and, supporting power mobility skills, were included to address use of power mobility with more complex populations as well as the child and family perspective.

Fifteen transferable messages addressing common questions or concerns such as age of introduction, impact on development, use with more complex children and environmental influences were developed. To assist clinicians in reflecting on the relevance of the evidence presented to their population and setting, case studies were included to illustrate examples of children from different age groups with a variety of needs who can benefit from use of power mobility.

The paper was presented for informal feedback and discussion at the International Seating Symposium, Nashville, March 2011. More than 200 participants participated in the first workshop and audience response technology was used to allow anonymous voting on the messages. Strong consensus was determined *a priori* to be above 70%. Any statements falling below this level of consensus were removed, modified or combined according to feedback from workshop participants during the open discussion period. Further feedback was received from a workshop involving 50 participants from a wide range of countries at the European Seating Symposium, Dublin, November 2011. Audience voting and discussion resulted in re-wording and refinement of some transferable messages and further feedback on the clinical utility of the paper.

In the revised paper, ten transferable messages supported by the literature were included. Two references were removed following this informal consensus and revision process^{23, 24} as workshop participants voted to eliminate the associated messages. Much of the research evidence was of lower strength with only one RCT identified.²⁵ One level III single-subject design²⁶ was identified, while four articles, achieving level IV evidence level, described the results of two group²⁷⁻²⁹ and one single-subject³⁰ design. There were 14 level V studies representing a number of group³¹⁻³⁵ and single³⁶⁻⁴¹ case-studies as well as cross-sectional designs.⁴²⁻⁴⁴ In addition, five qualitative studies were included.⁴⁵⁻⁴⁹

Formal feedback on the format, layout and content of the position paper were desired in order to ensure its suitability for use in a variety of international settings. A consensus of clinical experts is thought to be capable of supporting conclusions that the intervention in question may be reasonably supported, and equivalent to level III evidence.⁵⁰ We therefore sought to combine expert opinion with the existing lower level

research evidence in a rigorous manner in order to assist in providing stronger guidance for clinicians, families and funders regarding the use and benefits of power mobility for children.

The literature review was updated May 2012 prior to the formal consensus process. Newly published studies were included³⁵ and references updated for studies that had previously been included as theses or conference proceedings.^{25, 29} The AGREE II checklist⁵¹ was used to reduce bias and ensure quality in the development of the clinical practice considerations.

See Appendix 2 for evidence table of studies that met final inclusion criteria following the international consensus process.

PART II: INTERNATIONAL CONSENSUS PROCESS

This section of the article describes multiple rounds of expert review that were conducted to achieve consensus on the content and wording of several messages around which the paper was structured, as well as formal feedback on the scope, structure, content and layout of the paper.

Design

The Delphi technique is a method that uses sequential questionnaires or ‘rounds’ to gather information and establish consensus where there is uncertainty or lack of empirical evidence,⁵² providing an efficient and economical method to communicate with a geographically diverse panel of experts. Participants remain unknown to other participants, allowing individuals to express their opinions openly, without peer pressure. Between each round, participants are provided with group level of agreement and their own individual ratings to allow generation of knowledge and consensus building.⁵²

Participants:

Individuals who had published research or opinion pieces in peer-reviewed journals in the last 15 years or provided education on the use of power mobility with children at national or international levels in the last 5 years were approached to participate in the expert panel. To ensure global representation, expert clinicians from internationally renowned centers were also approached. 21 experts were approached, 19 consented to participate and 18 completed the first round. The expert panel included 11 occupational therapists, five physiotherapists, one psychologist and one engineer. Ten participants were primarily academics or researchers and eight were primarily clinicians. Participants were recruited from Canada, the United States (US), the United Kingdom (UK), Sweden and Australia. Human subjects ethics approval was obtained from the University of British Columbia and the Children’s & Women’s Health Centre of British Columbia Research Ethics Board.

Method:

This study involved a computer-based, online Delphi survey. Each participant was provided with a copy of the draft paper and invited to rate the content and relevance of the paper as well as their level of agreement with 10 transferable messages. Agreement was represented by responses on a 5-point Likert scale: 1= disagree strongly, 2= disagree, 3= neutral, 4= agree, 5= strongly agree. Narrative comments were solicited for each statement and on any section of the paper as well as suggestions for additional references or messages.

Procedure:

Following human subjects' ethics approval each expert was emailed an invitation to participate in the Delphi process. Experts who provided email consent for further contact were emailed the draft paper along with an individualized link to the survey tool. The draft paper included evidence levels to assist experts in making judgements about the quality of evidence supporting each statement. The survey was left open for five weeks.

Analysis:

In each of the three rounds expert ratings were summarized in a report by the survey tool with percentages of agreement calculated and content analysis determined themes among participants' responses to open-ended questions. These reports along with the revised paper and participants' individual responses were included with the second and third round surveys. Expert-suggested wording changes for the transferable messages and suggestions of additional material or refinement of the paper were considered for incorporation into revised versions.

Results for round 1:

Agreement percentages for each transferable message are summarized in Table 1.

Insert Table 1 about here

Only one message had less than 80% rating of 4 or 5. Message 9 generated some controversy over the definition of 'competent'. The paper was revised and terms used in the paper such as 'competent' 'proficient' and 'novice' were defined based on research.²⁴

Participants were asked whether they preferred having evidence levels with the statements or separately in a table. 66% agreed or strongly agreed with keeping the evidence levels with the statements, 22% were neutral and 22% disagreed. However 28% agreed or strongly wanted an evidence table while 39% were neutral and 33% disagreed. As a compromise, an evidence table was created as an appendix.

Changes to the layout and organization of the paper were guided by narrative feedback provided by the experts. One participant suggested that the four groupings of children who can benefit from power mobility were rather focused on physical limitations and diagnosis and suggested making them more functional.

ROUND 2

Seventeen participants from round 1 continued to participate in round 2. Nine transferable messages were included as consensus above 80% full agreement had been achieved for message 3 in round 1. Message 4 had also achieved full agreement but wording changes had been suggested. The survey was left open for six weeks.

Results for round 2

Consensus above 80% agreement (rating of 4) and full agreement (rating of 5) was achieved for all statements. Consensus above 80% full agreement was achieved for three messages (1,2, and 8). Level of agreement on message 4 went down from round 1 due to change of wording. See Table 2 for results.

Insert Table 2 about here

Wording changes were suggested for all messages and so all were included in the third round. Message 6 generated some controversy as some experts felt that it detracted from the main purpose and intent of the paper. As regards to organization and layout of the paper, the majority of participants preferred to retain the original four groupings of children (44% fully agreed and 28% agreed). The functional descriptions were worked into the text to ensure that the diagnoses were seen as examples and not as limiters.

ROUND 3

Eighteen experts were invited to participate with 16 completing round 3. Since wording changes had been suggested, all transferable messages were included for rating in this round. Experts were asked to vote on whether or not they agreed with the removal of message 6 from the paper. The survey was left open for seven weeks.

Results for round 3

The majority of participants agreed with the decision to remove message 6 from the paper. Some strongly felt that the content was important to include in the text but to relate it more broadly to all children with severe disabilities. Consensus above 80% ratings of 5 was achieved on messages 2, 5, 7 and 8. Consensus above 80% ratings of 4 and 5 was achieved on messages 1, 3, 4, 6, 9 and 10. See Table 3 for results.

Insert Table 3 about here

DISCUSSION AND FINAL VERSIONS OF TRANSFERABLE MESSAGES

Expert feedback on overall flow, readability, relevance and usefulness improved steadily over each round as the paper was revised and suggestions from participants were incorporated. The evidence table was revised to reflect only the studies that were used to support the transferable messages. The transferable messages shown below are the final versions that were selected to be included in the practice considerations paper. These are not necessarily the version included in round 3, but the version for which there was highest consensus.

1. ***With access to a specialized power mobility device, it is possible for infants with disabilities to have augmented experiences as early as 8 months of age.*** For this message, the strongest consensus occurred in round two: 82% (14/17) strongly agreed and the remaining 18% (3/17) agreed. Some participants suggested that 8 months was not early enough for some types of disability but consensus dropped with the change to ‘below 8 months of age’. Concerns were expressed that power mobility may be detrimental to infants below 8 months of age (R.Kermoian personal communication). This message is supported by level V case study evidence.^{39,40}
2. ***Children can begin learning to maneuver a power mobility device below 14 months of age and those able to use a joystick have demonstrated competent control as young as 18-24 months.*** Consensus was strongest in round three for this message with 94% (15/16) strongly agreeing. This message reflects the majority of early power mobility research that focused on age of use and included only children able to use joysticks.^{31,32,37,38} One early case study³⁶ described a child with no limbs learning to use a power mobility device using body movement and switches. A recent RCT²⁵ also included children with cognitive and communication limitations as well as children using head controls and switches.
3. ***For children with minimal mobility experience, a power mobility device can promote overall development as well as functional mobility.*** In round one, 94% (17/18) strongly agreed so this message was omitted from round two. However, participants suggested wording changes, i.e., ‘psychosocial’ to ‘overall’ and ‘support’ to ‘promote’. In round three, only 62% (10/16) strongly agreed and 19% (3/16) agreed. Of six experts who voted neutral or agree in round three instead of

- strongly agree as they had in round one, two comments favored changing back to the word ‘promote’ and one commented against ‘overall’ with preference for ‘psychosocial’. Generally, comments were in favor of having a more inclusive ‘overall’ rather than ‘psychosocial’. Consequently, ‘overall’ was retained in the final version. A recent theoretical paper⁵³ provides support for this decision. This message is supported by one level II study,²⁵ one level III study,²⁶ three level IV studies,²⁷⁻³⁰ two level V studies^{35,40} and two qualitative studies.^{45,46}
4. ***For children with inefficient mobility, power mobility may enhance independence and participation in family, school and community life.*** This is the version used in round one where it had the highest consensus with 83% (15/18) strongly agreeing and 11% (2/18) agreeing, with one person voting neutral. One participant suggested adding the words ‘in mobility’ to ‘independence’ but other participants disagreed and consensus dropped in round two. Round three rating was only 75% (12/16) strong agreement with addition of the word ‘meaningful’ before ‘participation’. This message is supported by Level V⁴² and qualitative evidence.^{47,48}
 5. ***There is no evidence that using power mobility at a young age impedes development of ambulation or other motor skills.*** Consensus was highest for this version in round three, with 88% (14/16) agreeing strongly, one person agreeing and one person voting neutral. In previous rounds, other versions of this message were felt to be too strong in relation to the level of evidence. This message is supported by one RCT²⁵ one level IV²⁷ and one level V study.³³
 6. ‘Power mobility devices for children with progressive neuromuscular disease should include specialized seating, powered seating functions and be capable of accommodating alternate drive controls and control of other assistive technology devices through the drive method’. This statement was removed as it was supported by weak Level V evidence⁴³ and related to only one population whereas; the statement itself was relevant to children with a wide variety of complex disabilities. Participants felt that this message detracted from the main flow and purpose of this paper but the content was included in paragraph form relating to all children with complex disabilities.
 7. ***Children with conditions that limit early functional mobility may benefit from power mobility to promote independence and support overall development.*** Round three had the highest consensus with 94% (15/16) strongly agreeing and one agreeing. This message is supported by one level V case-study.⁴⁰
 8. ***Mobility experience in a power mobility device may support development of self-initiated behavior and learning.*** This message was changed significantly in each round and consensus steadily rose with round three having the highest consensus: 94% (15/16) strongly agreed and one person was neutral. This message is supported by qualitative and case-study evidence.^{34,35,45,49}
 9. ***Many children with severe intellectual and/or sensory impairments can learn to use a power mobility device competently with appropriate practice and environmental support.*** This message was definitely more controversial but consensus rose significantly from 56% (10/18) strongly agreeing in round one to 75% (12/16) strongly agreeing and 12% (2/16) agreeing in round three. One

expert was neutral and another disagreed. This statement is supported by level IV,²⁷ level V³⁵ and qualitative evidence.^{45,49}

10. ***Successful learning of power mobility skills may depend at least as much on practice time and quality of learning support within the child's environment as the child's motor, cognitive or sensory abilities.*** Again, this was controversial, but consensus rose significantly from 61% (11/18) strongly agreeing in round one to 75% (12/16) strongly agreeing and 19% (3/16) agreeing in round three, with only one person disagreeing. This statement is supported by level IV,²⁷ level V⁴⁴ and qualitative evidence.⁴⁵

Limitations

Development of this paper was limited by the size and diversity of the international panel. Unfortunately, we were unable to secure more participants from some European countries due to language barriers and we did not secure any participants from Asia. A limitation common to Delphi surveys is the subjective process used to identify the participants. To attempt to reduce bias, we endeavored to contact all individuals who had published research or opinion pieces in peer-reviewed journals in the last 15 years and gave them the option to participate.

By including participants biased toward a particular viewpoint, our results may have been skewed. However, the clinicians and researchers who participated had a minimum of five years' experience working with children using power mobility. They came from a variety of different disciplines, backgrounds and clinical settings as well as from different countries. They had definite opinions and the Delphi process allowed them opportunities to contribute their ideas and to modify their opinions as they worked through the group process.

Conclusion

The resulting international consensus practice considerations paper is intended to provide guidance for clinicians, families and funders regarding the use and benefits of power mobility for children. It describes different groups of children who can benefit from use of power mobility and provides guidance on use and expectations for children at different ages and with different needs and abilities. The paper also provides some guidance on environmental influences that can impact on successful introduction and use of power mobility with children.

PART III: PRACTICE CONSIDERATIONS

This paper aims to combine evidence-based literature with expert opinion in order to make recommendations on decision-making and justification for power mobility use with infants, children and adolescents. It has been structured in three sections. The first describes different groups of children who benefit from use of power mobility, and includes six transferable messages. The second section discusses issues of 'readiness' and the process of learning power mobility skills for children with complex developmental needs. The benefit of power mobility experience for children who may never develop competent driving skills is included in this section along with two transferable messages. The final section discusses the environmental influences on power mobility skill development and includes one transferable message.

For the purposes of this paper, the term ‘power mobility skills’ describes the development of skill from the exploratory behavior of the novice through learning to control the functions of the power mobility device, to competent use in daily life. The term ‘competent’ is used to describe a child who has learned to operate the power mobility device, i.e., they can avoid obstacles and maneuver in a safe environment. Proficient use, where children can use judgment and focus on the activity rather than on controlling the device, can take many years.²⁴

The field of rehabilitation is undergoing a paradigm shift from considering power mobility as a final option, reserved for older children once all other forms of mobility have been tried and found ineffective, to a therapeutic modality that can be used to support development, exploration and participation for a wide range of infants and children with disabilities. Children and families may use a variety of mobility solutions depending on the environment or activity.⁵⁴ While not all children will become competent or proficient power wheelchair users, clinicians should consider power mobility as an accepted intervention even for very young children who do not have the ability to move and explore independently. The aim of this intervention is to address the secondary effects of lack of mobility on other areas of development such as socialization, cognition, visual-perception, and language.

Children’s use of power mobility should be commensurate with age-appropriate and developmental expectations. An infant using a power mobility device should be in a safe environment or have adult supervision and assistance. Older children with cognitive or sensory limitations may need adult supervision or assistance in the community (as they would if able to walk) but may learn to use a power wheelchair to meet their independent mobility needs.

General considerations for all children when introducing power mobility:

1. Identify the child’s postural abilities and needs for support when using the proposed device. Remember that the child will likely need more support when in a mobile system than when in a stationary seat. Postural supports should enhance the child’s abilities to use their hands (or other body parts) to activate the power mobility device.^{55,56}
2. Identify any limitations within the child’s visual, perceptual or sensory system. Visual, perceptual or sensory limitations do not preclude consideration of power mobility, but may require an alternative approach to training, compensatory strategies and/or technology.¹⁴
3. Consider the child’s developmental level. Children functioning at around a two-year-old cognitive level may start by driving the power mobility device in circles,³¹ but quickly move on to attempt to purposefully drive to a toy or person and are expected to become proficient drivers in time. Some children with more complex physical, cognitive or sensory limitations move relatively quickly from the exploratory behaviors of the novice to attempting to move towards a goal but may require a longer training period and more supervision to develop competent driving skills.²⁵ Some children functioning at very early developmental levels may never move beyond the exploratory behaviors of the novice but power mobility experience can stimulate overall development in areas such as initiation, head and hand control, visual attention and child-directed exploration that are also

important outcomes.⁴⁶ Knowing the child's developmental level guides clinicians as to the most appropriate device, approach or expectations for power mobility.

WHICH CHILDREN NEED POWER MOBILITY?

Four different groups of children can benefit from power mobility:²²

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.

1. Children who will never walk and need functional mobility:

Children in this group have a poor prognosis for functional mobility without use of power mobility. The group includes, but is not limited to, children with the following diagnoses: cerebral palsy (CP), Gross Motor Function Classification System⁵⁷ (GMFCS) levels IV and V; spinal muscular atrophy (SMA) types I and II or congenital muscular dystrophy; multiple limb deficiencies or severe arthrogryposis; congenital high-level spinal cord lesions; and osteogenesis imperfecta (OI) types II, III, and VIII.

Case example: Lisa

Lisa is a 2-year-old girl with congenital muscular dystrophy. Her joystick was modified to increase sensitivity and positioned in midline to allow her to use both hands. She became competent in power mobility skills within 6 hours and her parents felt confident that she would be able to use a power wheelchair in their home and community with age-appropriate supervision. A pediatric, international standard-compliant⁵⁸ power wheelchair with tilt was ordered to allow the family to transport the device in a wheelchair-accessible vehicle.

2. Children who have inefficient mobility

Children in this group have limited ability to walk or wheel a manual wheelchair but need more effective mobility through use of power mobility for energy conservation and efficiency. This group includes, but is not limited to, children with the following diagnoses: CP (GMFCS levels III and IV, and some adolescents at level II); C6 or C7 spinal cord injuries (SCI); thoracic meningomyelocele; and OI, types IV-VII. Children with arthritis or medical conditions may also have inefficient mobility at times.

In children with a disability, walking ability peaks well before adolescence⁵⁹ and gait often worsens and requires more energy as these children age.⁶⁰ Very small numbers of children with CP are able to propel manual wheelchairs efficiently⁶ and power mobility may enhance participation at school, outdoors and in the community.⁶¹ To achieve efficient mobility and meaningful participation, a child must be able to maintain the same speed (without undue effort) and access the same activities and environments as their peers.

Case example: Chase

Chase is a 12-year-old boy with thoracic-level meningomyelocele. He has been an efficient manual wheelchair user for a number of years and plays wheelchair basketball and sledge hockey. However, his kypho-scoliosis has progressed rapidly and Chase is experiencing chest pain when seated in an upright position for long periods.

Chase is on a waitlist for spinal instrumentation surgery and, following this, will not be allowed to wheel for at least six months. A power wheelchair with tilt has been prescribed for use at school and outdoors, while he continues to use his manual wheelchair in the home. Following surgery, Chase will be a fulltime power wheelchair user for at least 6 months and long-term may use power mobility outdoors and in the community to enhance participation with peers.

3. Children who lose the ability to walk, or to walk efficiently

These children may have a prognosis for increasing disability or have lost the ability to walk due to illness or injury. This group includes, but is not limited to, children with the following diagnoses: neuromuscular diseases, e.g., Duchenne muscular dystrophy, limb girdle dystrophy, type III SMA, Friedreich's ataxia; acquired brain injury (ABI); and SCI. These children have already experienced independent mobility at a young age and therefore power mobility is used to maintain participation in family, school and community life.

With progressive neuromuscular diseases, children can usually operate a standard joystick initially⁶² and learn power mobility skills quickly.³⁸ Children with ABI often have more complex learning needs.⁶³ Children with high-level SCI are usually unable to access a standard joystick.¹² Access options for these children typically involve movements of the head or face and include chin joystick, mouth switches or joystick, sip and puff or proximity head array. An assessment by a clinician specialized in alternate access methods for power mobility may be helpful.

Clients with muscular dystrophy gradually lose ability to use a standard joystick but can regain full independence by using alternative driving methods.⁶² It is important to select a power wheelchair that will meet the client's needs for speed and outdoor performance and electronics that can accommodate changing needs as well as integrating power seating functions, medical equipment (ventilator, suction, G-tube pumps etc.), electronic aids to daily living and computer access.⁴³

Case example: Nikki

Nikki was diagnosed with limb girdle dystrophy at 8 years of age. Although she was able to walk independently and to wheel a manual wheelchair, her muscle disease progressed rapidly and an indoor/outdoor power wheelchair with tilt-in-space and expandable electronics was recommended. The funder declined the expandable electronics and reluctantly agreed to include tilt.

Three years later, Nikki is completely wheelchair-dependent. She has a rapidly progressive scoliosis and uses contoured seating. She constantly uses her tilt system to change position and increase comfort. Recline and lateral tilt options are being considered to address respiratory and pain issues. Nikki is also having difficulty exerting enough pressure to operate the standard joystick. The funder will now have to pay for an expensive upgrade to the electronics in order to accommodate the provision of a more sensitive joystick and integration of seating functions through the driver control.

4. Children who require mobility assistance in early childhood

Children need efficient, effortless, functional mobility early in childhood even if they will later use other means of mobility. This group includes, but is not limited to, children with the following diagnoses: arthrogryposis (surgical intervention may allow walking at

older ages); lumbar-level spina bifida (ambulation and efficient manual wheelchair use may be achieved in later childhood); OI (interventions such as intra-medullary rodding may allow walking at older ages); and CP (GMFCS Level III).

Case example: Maya

Maya is a 3-year-old girl with type IV OI. She has had intra-medullary rodding of her femurs and professionals in her specialized clinic anticipated that she would stand and walk by this age. However she has not progressed beyond independent sitting due to frequent upper limb fractures. Maya learned to steer a power wheelchair within a few minutes practice and a pediatric international standard compliant⁵⁸ power wheelchair with seat elevator was prescribed to give her a means of effortless, independent mobility and increased access to activities in her environment. Maya's joystick was modified to allow it to be easily transferred from left to right side due to her frequent fractures and a custom foot box was provided for protection while she develops proficiency.

Transferable messages related to children who can benefit from power mobility:

With access to a specialized power mobility device, it is possible for infants with disabilities to have augmented mobility experiences as early as 8 months of age.

Evidence: Level V.^{39,40} This research challenges the lower age limit for considering power mobility. In order to limit the impact of physical disability on overall development, clinicians should consider augmenting independent mobility opportunities around the same age as children typically begin to crawl. In these case reports, the specialized power mobility device was fitted with a supportive infant seat and could be remotely controlled by an adult to ensure safety.

Children can begin learning to maneuver a power mobility device below 14 months of age and those able to use a joystick have demonstrated competent control as young as 18 to 24 months. Evidence: Level II,²⁵ Level V.^{31,32,36-38}

The majority of power mobility research addresses the age of successful use with most studies having focused on children using joysticks. Children who are unable to use a joystick efficiently may benefit from an assessment to identify a more appropriate access method. Children who use alternate access methods (that are more cognitively challenging than a joystick) or who have additional visual, perceptual, cognitive or communication disabilities may require a longer time to learn power mobility skills or may require more specialized training.

For children with minimal mobility experience, a power mobility device can promote overall development as well as functional mobility. Power mobility experience appears to have a broad impact on development. The supporting evidence is divided into different domains for ease of understanding but it should be recognized that these areas are interwoven and all emerge from and have intellectual underpinnings.

Cognition: Evidence: Level V.⁴⁰

Receptive language: Evidence: Level II,²⁵ Level V.⁴⁰

Social and play skills: Evidence: Level IV,^{28,29} Level V.⁴¹

Independence: Evidence: Level IV.²⁷

Cause-effect: Evidence: Level V.³⁵

Self-initiated movement: Evidence: Level III,²⁶ Level IV,³⁰ Qualitative.^{45,46}

For children with inefficient mobility, power mobility may enhance independence and facilitate participation in family, school and community life.

Evidence: Level V;⁴² Qualitative.^{47,48} Children need an efficient means of mobility to move around the classroom and playground and to keep up with friends in the community. Using a power wheelchair can help save energy for learning and play with others. Adolescents need safe and efficient mobility choices and some, who can walk or use a manual wheelchair, also use power mobility to enhance participation in school and community life. The need for exercise should be addressed at other times and by other more effective means.

There is no evidence that using power mobility at a young age impedes development of ambulation or other motor skills. Evidence: Level II;²⁵ Level IV;²⁷ Level V.³³ Power mobility does not appear to negatively affect motor development and it has been suggested that children may be more motivated to use their motor skills and participate in therapy once they have experienced the independence that power mobility can provide.

Children with conditions that limit early functional mobility may benefit from power mobility to promote independence and support overall development. Evidence: Level V.⁴⁰

LEARNING POWER MOBILITY SKILLS

Children begin power mobility by exploring movement and learning to control direction. Gradually, they start to develop functional mobility skills. Competence in using the chair in daily life emerges first, but proficiency occurs only over time and with experience.²⁴ Readiness assessments such as the Pediatric Power Wheelchair Screening Test have been used to identify children who will quickly and easily learn to use a joystick-operated power wheelchair. This screening is not appropriate for children with multiple and complex disabilities who may use switches or other access methods.²³ Instead of focusing on readiness skills or passing a 'driving test,' clinicians should consider augmenting mobility at an early age for children who are unlikely to walk, in order to promote overall development and help lessen the secondary effects of immobility.

Transferable messages related to learning power mobility skills:

Mobility experience in a power mobility device may support development of self-initiated behavior and learning. Evidence: Level V;^{34,35} Qualitative.^{45,49}

For children with delayed cognitive and physical development, use of a power mobility device may facilitate overall learning. Movement of the device provides immediate feedback, as well as vestibular and visual stimulation, when the child activates the joystick or switch. Some of these children may never develop competent use of a power mobility device but still benefit from the independent mobility experience.

Many children with severe intellectual and/or sensory impairments can learn to use a power mobility device competently with appropriate practice and environmental support.

Evidence: Level IV;²⁷ Level V;³⁵ Qualitative.^{45,49} These children may need extensive experience and training to be successful.⁴⁹ Some children will always require adult supervision to ensure safety but a power mobility device can allow spontaneous exploration in a safe environment which will promote overall development.⁴⁶ For young

children, learning power mobility skills is not like an adolescent with typical mobility learning to drive a car, but is similar to a child learning to walk or to use a tricycle.⁶⁴ The adult needs to be a 'responsive partner' and to help elicit children's learning through play rather than interfering with their concentration by talking and directing.²⁴ The amount and type of training will vary with the individual, their needs, deficits, motivations, and learning styles. Even those with severe visual impairment can use power mobility with adaptations, such as use of a cane or a specialized wheelchair with sensors.⁴⁵

Case example of a child with more complex developmental needs: Oliver

Oliver has dyskinetic CP (GMFCS level V). He is non-verbal and cognitive testing is unreliable; however, he makes choices through eye gaze. Oliver has some independent mobility in a supportive gait trainer but this can only be used indoors on smooth surfaces.

At age 6, Oliver's ability to target switches with his hands was erratic and effortful. He was loaned an old power wheelchair with a proportional head control to develop the initial skill of learning to keep his head up to activate the chair and dropping his head to stop. After 6 months of training, he tried different types of head control devices and was most successful with small mechanical switches. One was positioned behind his head with right and left turn switches by his cheeks.

After 5 years, Oliver is a proficient driver. His switches were recently changed to a proximity style and are arranged close to the back of his head. He is able to drive through doorways and in crowded corridors, showing good judgment and safety awareness. His family has a wheelchair accessible van and a new, more powerful power wheelchair has been ordered in preparation for high school.

SUPPORTING POWER MOBILITY SKILLS

Initially, parents may view power mobility negatively but once their children have power mobility experience, most describe positive feelings related to seeing their child experiencing independence and control.^{27,47} Families describe power mobility as leading to increased integration and participation by their children with other children but note that appropriate training and support are major factors in successful use.⁶⁵ Aspects of the physical, social and cultural environment can have a great influence on power mobility use, as well as personal factors such as motivation, goals and priorities.

At this time, power wheelchairs are often large and difficult to transport. This can be a major barrier for families incorporating one into a child's life. The development of less expensive and more child-and family-friendly options, such as ride-on-toy cars, may help to reduce this barrier.⁶⁶ Standard power wheelchairs do not appear to facilitate reach and interaction with toys.²⁹ Development of inexpensive, lightweight, child- and family-friendly power mobility devices to facilitate participation in play, home and preschool environment is needed.

To enhance power wheelchair use without contributing to problems of posture and pain, supportive seating, powered seating functions and adequate suspension are important features to consider.⁴⁸ For children with progressive or severe and complex disabilities, power wheelchairs should be ordered with electronics capable of accommodating alternate access technologies, integration of powered seating functions and control of other assistive technologies such as communication, computer or

electronic aids to daily living through the drive controls.⁴³ These features are often needed to promote optimal participation and independence through the power wheelchair.

Clinicians may have difficulty accessing power mobility devices for extended trial and training for children who do not immediately demonstrate ability to maneuver and control the device safely.⁶⁷ Developing relationships with wheelchair providers in order to borrow power wheelchairs for longer periods may help address this barrier. Power mobility experience can also be provided with powered toys, cars, standers, recycled or shared wheelchairs during therapy sessions.

Transferable message related to supporting power mobility skills:

Successful development of power mobility skills may depend at least as much on practice time and quality of learning support within the child's environment as the child's motor, cognitive or sensory abilities. Evidence: Level IV,²⁷ Level V,⁴⁴ Qualitative.⁴⁵ To learn any new skill, all children need extensive practice. Identifying where the child is in the learning process, providing a suitable environment (including an appropriately programmed power mobility device) and learning strategies is critical to success.⁴⁹ Children who are given more time and experience using a power mobility device, and who are supported in their learning by those around them, are more likely to be successful in developing power mobility skills.

CONCLUSION

Use of power mobility enhances independence and overall development in young children who do not walk.^{25,27-29} In children who have inefficient mobility or lose the ability to walk, power mobility enhances activity and participation.^{47,48} Without efficient, independent mobility, young children are at risk of developing passive, dependent behaviour²⁶ and older children are at risk of decreased participation and isolation. Mobility should be effortless and allow children and adolescents the opportunity to participate fully in age-appropriate and meaningful activities.⁵⁴ All children who lack efficient independent mobility should be considered for power mobility and not excluded on the basis of age, limited vision, early developmental level, physical access limitations, or the ability to use other means of mobility for short distances.

Acknowledgements

The authors wish to thank Debra A. Field OT, PhD candidate for acting as second reviewer in determining levels of evidence for included studies. We would like to thank the 16 members of the international review panel who took part in the Delphi process: Jacqueline Casey,^a Stephanie Chapman,^b Josephine Durkin,^c Debra A. Field,^d Jan Furumasu,^e James C (Cole) Galloway,^f Marlene Holder,^g Maria Jones,^h Karen Kangas,ⁱ Rosanne Kermoian,^j Michelle Lange,^k Sarah McGarry,^l Lisbeth Nilsson,^m Paul Nisbet,ⁿ Elisabet Rodby-Bousquet,^o Tylie Stokes.^b Finally, we would like to acknowledge Susan R. Harris, PT, PhD for her editorial expertise in preparing this manuscript for publication.

^aMSc, BSc(Hons)OT, PgCHEP, Lecturer in Occupational Therapy, School of Health Sciences, University of Ulster, Northern Ireland, UK

^bBSc Senior Specialist Occupational Therapist, Chailey Heritage Clinical Services, UK

^cDip COT, PhD, Independent consultant Occupational Therapist in neuro-disability, UK

- ^dMHScOT, PhD Candidate, University of British Columbia, Graduate Programs in Rehabilitation Science and Sunny Hill Health Centre for Children, BC, Canada
- ^ePhysical Therapist, ATP, Rancho Los Amigos National Rehabilitation Center, California, USA
- ^fProfessor, Director of Infant Behavior lab, Dept of Physical Therapy, University of Delaware, Newark, DE, USA
- ^gBSc OT, Holland Bloorview Kids Rehabilitation Hospital, ON, Canada.
- ^hPT, PhD, University of Oklahoma Health Sciences Centre, Department of Rehabilitation Sciences, OK, USA
- ⁱOccupational Therapist, Assistive Technology Specialist, Clinical Educator and Adjunct Faculty, Misericordia University, Dallas, PA, USA
- ^jPhD, Senior Research Scientist, Stanford University, California, USA
- ^kOTR, ARDA, ATP/SMS, Access to Independence Inc, USA
- ^lBScOT(Hons), Senior Occupational Therapist Princess Margaret Hospital for Children, PhD Candidate Edith Cowan University, WA, Australia.
- ^mPhD, Reg Occupational Therapist, associated Lund University, Sweden.
- ⁿSenior Research Fellow, Communication, Access, Literacy and Learning (CALL) Scotland, University of Edinburgh
- ^oRPT, PhD, Centre for Clinical Research, Uppsala University, Västerås. Sweden.

References

1. Campos, JJ; Anderson, DI; Barbu-Roth, MA; Hubbard, EM; Hertenstein, MJ; Witherington D. Travel broadens the mind. *Infancy*. 2000;1(2):149–219.
2. Kermoian R. Locomotion experience and psychological development in infancy. In: J Furumasu, ed. *Pediatric powered mobility: Developmental perspectives, technical issues, clinical approaches*. Arlington, VA: RESNA; 1997:7–22.
3. Uchiyama I, Anderson DI, Campos JJ, et al. Locomotor experience affects self and emotion. *Dev Psychol*. 2008;44:1225–31.
4. Butler C. Wheelchair toddlers. In: J Furumasu, ed. *Pediatric powered mobility: Developmental perspectives, technical issues, clinical approaches*. Arlington, VA: RESNA; 1997:1–6.
5. Rodby-Bousquet E, Hägglund G. Use of manual and powered wheelchair in children with cerebral palsy: A cross-sectional study. *BMC Pediatr*. 2010;10:59.
6. Dijkers MP, Bushnik T, Heinemann AW et al. Systematic reviews for informing rehabilitation practice: An introduction. *Arch Phys Med Rehabil*. 2012; 93:912-8.
7. Levac D, Colquhoun H, O'Brien KK. Scoping studies: advancing the methodology. *Implementation Science*. 2010; 5:69.

8. Law M, Stewart D, Pollock N et al. Critical review form: Quantitative studies. 1998. Available at: <http://www.canchild.ca/en/canchildresources/resources/quantform.pdf>. Accessed January 6, 2013.
9. Letts L, Wilkins S, Law M et al. Critical review form: Qualitative studies (Version 2.0). 2007. Available at: <http://www.canchild.ca/en/canchildresources/educationalmaterials.asp#CriticalReview>. Accessed April 20, 2013.
10. Lavis JN, Robertson D, Woodside JM et al. How can research organizations more effectively transfer research knowledge to decision makers? *Millbank Quart.* 2003; 81:221-48.
11. Livingstone R. Beginning power mobility: A knowledge translation activity. *OT Now.* 2009;11(6):21-4.
12. Douglas J; Ryan M. A preschool severely disabled boy and his powered wheelchair: A case study. *Child: Care, Health Dev.* 1987;13:303-9.
13. Pope P, Bowes C, Booth E. Postural control in sitting, the SAM system: Evaluation and use over three years. *Dev Med Child Neurol.* 1994; 36:241-52.
14. Nisbet P; Craig J; Odor P; Aitken S. "Smart" wheelchairs for mobility training. *Technol Disabil.* 1996;5:49-62.
15. Benedict RE, Lee JP, Marrujo SK, Farel AM. Assistive devices as an early childhood intervention: evaluating outcomes. *Technol Disabil.* 1999; 11:79-90.
16. Nisbet PD, Assessment and training of children for power mobility in the UK. *Technol Disabil.* 2002;14:173-82.
17. Ostensjø S, Carlberg E, Vøllestad N. The use and impact of assistive devices and other environmental modifications on everyday activities and care in young children with cerebral palsy. *Disabil Rehabil.* 2005; 27:849-61.
18. Huhn K, Guerrero-Bowlby P, Deutsch J. The clinical decision-making process of prescribing power mobility for a child with cerebral palsy. *Pediatr Phys Ther.* 2007; 19:254-60.
19. Frank A, Neophytou C, Frank J et al. Electric powered indoor-outdoor wheelchairs (EPIOC's): Users' views of influence on family, friends and carers. *Disabil Rehabil Assist Technol.* 2010; 5:327-38.
20. May M, Rugg S. Electrically powered indoor/outdoor wheelchairs: Recipients' views of their effects on occupational performance and quality of life. *Br J Occup Ther.* 2010; 73:2-12.

21. AACPDM. Methodology to develop systematic reviews of treatment interventions (Revision 1.2). American Academy of Cerebral Palsy and Developmental Medicine. Available at: <http://www.aacpdm.org/publications/outcome/resources>. Accessed January 8, 2011.
22. Hays RM. Childhood motor impairments: clinical overview and scope of the problem. In: KM Jaffe, ed. *Childhood Powered Mobility: Developmental, Technical and Clinical Perspectives*. Seattle, Washington: RESNA; 1987:1–10.
23. Furumasu J, Guerette P, Tefft D. Relevance of the Pediatric Powered Wheelchair Screening Test for children with cerebral palsy. *Dev Med Child Neurol*. 2004;46:468–74.
24. Durkin J. Discovering powered mobility skills with children: 'responsive partners' in learning. *Int J Ther Rehabil*. 2009;16(6):331–42.
25. Jones MA., McEwen IR, Neas BR. Effects of power wheelchairs on the development and function of young children with severe motor impairments. *Ped Phys Ther*. 2012;24:131–40.
26. Butler C. Effects of powered mobility on self-initiated behaviors of very young children with locomotor disability. *Dev Med Child Neurol*. 1986;28:325–32.
27. Bottos M, Bolcati C, Sciuto L, Ruggeri C, Feliciangeli A. Powered wheelchairs and independence in young children with tetraplegia. *Dev Med Child Neurol*. 2001;43:769–77.
28. Tefft D, Guerette P, Furumasu J. The impact of early powered mobility on parental stress, negative emotions, and family social interactions. *Phys Occup Ther Pediatr*. 2011;31(1):4–15.
29. Guerette P, Furumasu J, Tefft D. The positive effects of early powered mobility on children's psychosocial and play skills. *Assist Technol*. 2013;25:39–48.
30. Deitz J, Swinth Y, White O. Powered mobility and preschoolers with complex developmental delays. *Am J Occup Ther*. 2002;56:86–96.
31. Butler C, Okamoto G, McKay T. Motorized wheelchair driving by disabled children. *Arch Phys Med Rehabil*. 1984;65:95–7.
32. Butler C, Okamoto GA, McKay TM. Powered mobility for very young disabled children. *Dev Med Child Neurol*. 1983;25:472–4.
33. Paulsson K; Christofferson M. Psychosocial aspects on technical aids - How does independent mobility affect the psychosocial and intellectual development of children with physical disabilities? In: *2nd international conference on rehabilitation engineering*. Ottawa; 1984:282–86.

34. Nilsson L, Nyberg P. Single-switch control versus powered wheelchair for training cause-effect relationships: case studies. *Technol Disabil.* 1999;11:35–8.
35. McGarry S, Moir L, Girdler S. The smart wheelchair: Is it an appropriate mobility training tool for children with physical disabilities? *Disabil Rehabil: Assist Technol.* 2012;7:372–80.
36. Zazula J, Foulds R. Mobility device for a child with phocomelia. *Arch Phys Med Rehabil.* 1983;64:137–9.
37. Everard L. The wheelchair toddler. *Health Visit.* 1984;57:241–2.
38. Jones MA, McEwen IR, Hansen L. Use of power mobility for a young child with spinal muscular atrophy. *Phys Ther.* 2003;83:253–62.
39. Galloway JC, Ryu J-C, Agrawal SK. Babies driving robots: Self-generated mobility in very young infants. *Intel Serv Robot.* 2008;1:123–34.
40. Lynch A, Ryu J-C, Agrawal S, Galloway JC. Power mobility training for a 7-month-old infant with spina bifida. *Ped Phys Ther.* 2009;21:362–8.
41. Ragonesi CB, Chen X, Agrawal S, Galloway JC. Power mobility and socialization in preschool: A case study of a child with cerebral palsy. *Pediatr Phys Ther.* 2010;22:322–9.
42. Wiart L, Darrah J, Cook A, Hollis V, May L. Evaluation of powered mobility use in home and community environments. *Phys Occup Ther Pediatr.* 2003;23(2):59–75.
43. Richardson M, Frank AO. Electric powered wheelchairs for those with muscular dystrophy: Problems of posture, pain and deformity. *Disabil Rehabil: Assist Technol.* 2009;4:181–8.
44. Nilsson L, Nyberg P, Eklund M. Training characteristics important for growing consciousness of joystick-use in people with profound cognitive disabilities. *Int J Ther Rehabil.* 2010;17:588–95.
45. Odor P; Watson M. *Learning through Smart Wheelchairs: A formative evaluation of the CALL centre's smart wheelchairs as part of children's emerging mobility, communication, education and personal development.* Final report to the Nuffield Foundation and the Scottish Office Education Department, Edinburgh; 1994. Available at: http://callcentre.education.ed.ac.uk/Smart_Wheelch/Res Accessed 2005 Jan 25.
46. Nilsson LM, Nyberg PJ. Driving to learn: A new concept for training children with profound cognitive disabilities in a powered wheelchair. *Am J Occup Ther.* 2003;57:229–33.

47. Wiart L, Darrah J, Hollis V, Cook A, May L. Mothers' perceptions of their children's use of powered mobility. *Phys Occup Ther Pediatr*. 2004;24(4):3–21.
48. Evans S, Neophytou C, De Souza L, Frank AO. Young people's experiences using electric powered indoor - outdoor wheelchairs (EPIOCs): Potential for enhancing users' development? *Disabil Rehabil*. 2007;29:1281–94.
49. Nilsson L, Eklund M, Nyberg P, Thulesius H. Driving to learn in a powered wheelchair: The process of learning joystick use in people with profound cognitive disabilities. *Am J Occup Ther*. 2011;65:652–660
50. Johnston M, Dijkers M. Toward improved evidence standards and methods for rehabilitation: recommendations and challenges. *Arch Phys Med Rehabil*. 2012; 93:S185-99.
51. AGREE Next Steps Consortium. Appraisal of Guidelines for Research and Evaluation II. AGREE II Instrument 2009. Available from: <http://www.agreetrust.org>. Accessed 20, April 2013.
52. Powell C. The Delphi technique: myths and realities. *J Adv Nurs*. 2003;41:376–82.
53. Lobo M, Harbourne R, Dusing S et al. Grounding early intervention: physical therapy cannot just be about motor skills any more. *Phys Ther*. 2013; 93:94-103.
54. Wiart L, Darrah J. Changing philosophical perspectives on the management of children with physical disabilities - their effect on the use of powered mobility. *Disabil Rehabil*. 2002;24(9):492–8.
55. Lacoste M, Therrien M, Prince F. Stability of children with cerebral palsy in their wheelchair seating: Perceptions of parents and therapists. *Disabil Rehabil: Assist Technol*. 2009;4:143–50.
56. Stavness C. The Effect of Positioning for Children with Cerebral Palsy on Upper-Extremity Function: A review of the evidence. *Phys Occup Ther Pediatr*. 2006;26(3):39–54.
57. Palisano R, Rosenbaum P, Walter S, Russell D, Wood E, Galuppi B. Development and reliability of a system to classify gross motor function in children with cerebral palsy. *Dev Med Child Neurol*. 1997;39:214–23.
58. International Standards Organization. ISO 10542 Wheelchair tiedown and occupant restraint systems. 2004. Available at: www.iso.org/iso/iso_catalogue_tc/catalogue_detail.htm?csnumber=30297. Accessed 2012 May 25.

59. Hanna SE, Rosenbaum PL, Bartlett DJ, et al. Stability and decline in gross motor function among children and youth with cerebral palsy aged 2 to 21 years. *Dev Med Child Neurol*. 2009;51:295–302.
60. Johnston TE. Energy cost of walking in children with cerebral palsy: relation to the gross motor function classification system. *Dev Med Child Neurol*. 2004;46:34–8.
61. Palisano RJ, Hanna SE, Rosenbaum PL, Tieman B. Probability of walking, wheeled mobility, and assisted mobility in children and adolescents with cerebral palsy. *Dev Med Child Neurol*. 2010;52:66–71.
62. Pellegrini N, Guillon B, Prigent H, et al. Optimization of power wheelchair control for patients with severe Duchenne muscular dystrophy. *Neuromusc Disord: NMD*. 2004;14:297–300.
63. Hall DM, Johnson SL, Middleton J. Rehabilitation of head injured children. *Arch Dis Child*. 1990;65:553–6.
64. Kangas K. Powered mobility training for children. In: *18th International Seating Symposium*. Vancouver, BC; 2002:1–5. Available at: www.seatingandmobility.ca/libraries/word_document/019Powered. Accessed 2012 Jan 26.
65. Berry ET, McLaurin SE, Sparling JW. Parent/caregiver perspectives on the use of power wheelchairs. *Ped Phys Ther*. 1996;8:146–50.
66. Huang H-H, Galloway JC. Modified Ride-on Toy Cars for Early Power Mobility. *Pediatr Phys Ther*. 2012;24:149–154.
67. Guerette P, Tefft D, Furumasu J. Pediatric powered wheelchairs: Results of a national survey of providers. *Assist Technol*. 2005;17:144–58.

Table 1

Statement	1 Strongly disagree	2 disagree	3 neutral	4 agree	5 Fully agree
1. With access to a specialized PMD, it is possible for infants with disabilities to have augmented mobility experiences at 8 months of age, when their peers are beginning to move				39%	61%
2. Children can begin learning to steer a PMD around 14 months and those able to use a joystick can achieve competent control as young as 18-24 months		6%	11%	33%	50%
3. For children with minimal mobility experience, a PMD can promote psycho-social development as well as functional mobility			6%		94%
4. For children with inefficient mobility, PM may enhance independence and participation in family, school and community life			6%	11%	83%
5. Using PM at a young age will not impede development of ambulation or other motor skills				39%	61%
6. PMD's for children with progressive neuromuscular disease should include specialized seating, powered seating functions and be capable of accommodating alternate drive controls and additional assistive technology			6%	33%	61%
7. Children with conditions that limit early functional mobility may benefit from PM to promote overall independence and psycho-social development		6%		22%	72%
8. Children who have poorly established cause-effect may benefit from practise in a PMD			11%	22%	67%
9. Children with severe intellectual and/or sensory impairments can learn to use a PMD competently	6%	6%	11%	22%	56%
10. Time spent practising and environmental support are very important, and can have more influence on successful learning of PM skills than differences in children's motor, cognitive or sensory abilities	6%		11%	22%	61%

Table 2

Statement	1 Strongly disagree	2 disagree	3 neutral	4 agree	5 Fully agree
1. With access to a specialized PMD, it is possible for infants with disabilities to have augmented mobility experiences as early as 8 months of age.				18%	82%
2. Children can begin learning to maneuver a PMD as early as 14 months and those able to use a joystick may demonstrate competent control as young as 18-24 months			6%	12%	82%
4. For children with inefficient mobility, PM may enhance independence in mobility and meaningful participation in family, school and community life	6%	18%	6%	12%	59%
5. Using PM at a young age has not been shown to impede development of ambulation or other motor skills		6%	6%	18%	71%
6. PMD's for children with progressive neuromuscular disease should include specialized seating, powered seating functions and be capable of accommodating alternate drive controls and control of other assistive technology devices through the drive method.			12%	24%	65%
7. Children with conditions that limit early functional mobility may benefit from PM to promote overall independence and psycho-social development		6%	6%	18%	71%
8. Mobility experience in a PMD may support skill development for children learning cause-effect relationships	6%	6%	6%		82%
9. Children with severe intellectual and/or sensory impairments can learn to use a PMD competently with appropriate practise and environmental support		6%	6%	12%	76%
10. Successful learning of PM skills may depend at least as much on practise time and support within the child's environment as the child's motor, cognitive or sensory abilities		6%		18%	76%

Table 3

Statement	1 Strongly disagree	2 disagree	3 neutral	4 agree	5 Fully agree
1. With access to a specialized PMD, it is possible for infants with disabilities to have augmented mobility experiences below 8 months of age.		12%	6%	31%	50%
2. Children can begin learning to maneuver a PMD below 14 months of age and those able to use a joystick have demonstrated competent control as young as 18-24 months		6%			94%
3. For children with minimal mobility experience, a PMD can support overall development as well as functional mobility			19%	19%	62%
4. For children with inefficient mobility, PM may enhance independence and meaningful participation in family, school and community life			12%	12%	75%
5. There is no evidence that using PM at a young age impedes development of ambulation or other motor skills			6%	6%	88%
6. PMD's for children with progressive neuromuscular disease should include specialized seating, powered seating functions and be capable of accommodating alternate drive controls and control of other assistive technology devices through the drive method. REMOVAL		12%	6%	44%	38%
7. Children with conditions that limit early functional mobility may benefit from PM to promote overall independence and support overall development				6%	94%
8. Mobility experience in a PMD may support development of self-initiated behaviour and learning			6%		94%
9. Many children with severe intellectual and/or sensory impairments can learn to use a PMD competently with appropriate practise and environmental support		6%	6%	12%	75%
10. Successful learning of PM skills may depend at least as much on practise time and quality of learning support within the child's environment as the child's motor, cognitive or sensory abilities		6%		19%	75%