Power Mobility Training for a 7-Month-Old Infant with Spina Bifida

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Purpose: Power mobility is a critical assistive technology for many children with special needs. Our previous work suggests that certain infants younger than the age 1 year of age can participate in formal power mobility training. **Key Points:** This case report describes the feasibility of providing a power mobility training program with a young infant with spina bifida. Specifically, we longitudinally quantified the infant's driving ability with a joystick-controlled device (UD1), using UD1's onboard computer and video camera from an infant's age of 7 to 12 months. During the training period, the infant improved in all driving variables. The infant's Bayley III cognition and language scores also increased at a rate greater than his chronological age. **Conclusions/Implications for Clinical Practice:** These results suggest that power mobility training within the first year of life may be appropriate for certain populations at risk of immobility. **(Pediatr Phys Ther 2009;21:362–368)** *Key words: child development, exploratory behavior, infant behavior, locomotion, mobility limitations, physical therapy/methods, robotics, spina bifida/open*

INTRODUCTION

In infants developing typically, the emergence of independent locomotion is associated with advances in perception, cognition, motor, and social skills.[1,2] Infants with certain neurological or orthopedic impairments, such as those with Down syndrome, generalized hypotonia, and hip dysplasia, have limited mobility in the first year but are expected to gain independent locomotion in the second year. Other infants, such as those with cerebral palsy, spinal muscular atrophy, and spina bifida, often display significantly limited mobility or a complete lack of mobility in the first year with long-term impairments that limit or preclude independent walking.[3,4]

In addition to the primary effects of immobility on the musculoskeletal and cardiovascular systems, immobility limits a child's exploratory experiences, which are thought to be important for typical development and quality of life.[5,6] For example, even mild motor impairments have been associated with global social and cognitive delays.[7,8] Although these studies suggest that children with mobility impairments may benefit from early power mobility, these studies often relied on qualitative measures and focused on children aged 2 years and older. This case report focuses on the assessment of power mobility training in an infant with spina bifida beginning at the age of 7 months.

The current standard of clinical practice in the United States for power wheelchair training is that children must demonstrate certain prerequisite abilities before they are eligible.[9] As a result, power mobility training, based on readiness, is offered clinically to children between 2 and 6 years of age, with 3 years being the average age of the youngest child being recommended for a power chair.[10]

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Our laboratory recently began empirical work on the effect of early access to power mobility in both infants developing typically and those with special needs. In the first study, we provided 2 infants younger than 14 months of age who were not yet walking, one developing typically and another with Down syndrome, with supervised but unstructured opportunities to sit in and play with an experimental joystick-driven power mobility device (UD1). These opportunities occurred 2 to 3 times per week for 6 weeks (Fig. 1). Both infants increased their total session time, percentage of session time spent driving, and total path length.[11] We next began a larger structured training study of early power mobility in infants developing typically. During this follow-up study, we were contacted by the family of an infant with significant mobility impairments caused by spina bifida. The infant was not developing typically and therefore was not eligible for the group study. However, our research team believed that this infant was appropriate for training. This prospective clinical case report presents the results of this training.

Spina bifida, a neural tube defect involving incomplete closure of the spine, leads to spinal cord lesions contributing to motor and sensory deficits below the level of the lesion. Myelomeningocele is a protrusion of the spinal cord through the spinal opening with partial or complete paralysis of the trunk and/or legs.[12] Myelomeningocele is the most severe and most common type of spina bifida, with annual cases as high as 0.20 per 1000 births.[12] Infants with lumbar-level myelomeningocele are appropriate candidates for power mobility training for 2 reasons. First, the vast majority of these infants will not ambulate during infancy, with most walking after 2 years of age. Furthermore, although some gain ambulation for short distances, more than 25% of children with a lumbar lesion will use a wheelchair for functional mobility throughout their life.[13] Second, although these infants have poor trunk and leg movements, they have upper extremity function adequate to operate a joystick. It is important to note that the child continued to receive the standard of care physical therapy interventions throughout the study period. Thus, there were no significant concerns that power mobility training would negatively affect the overall early intervention program.

The first purpose of this report was to evaluate the feasibility of providing a 7-month-old infant with spina bifida with structured opportunities ("training") to explore his environment with an experimental joystick-driven power mobility device. The second purpose was to quantify his driving performance. In addition to these primary purposes, we also assessed his general development over the multimonth training period. Participation in this case study commenced after receipt of informed consent from his parents as approved by the Human Subjects Review Board at the University of Delaware.

DESCRIPTION OF THE CASE

This report describes the performance of a 7-month-old infant, who has a diagnosis of the L4 to L5 myelomeningocele form of spina bifida on his birth at full-term. At study onset, he was a happy and socially engaging 7 month old who presented with significant limitations in bilateral

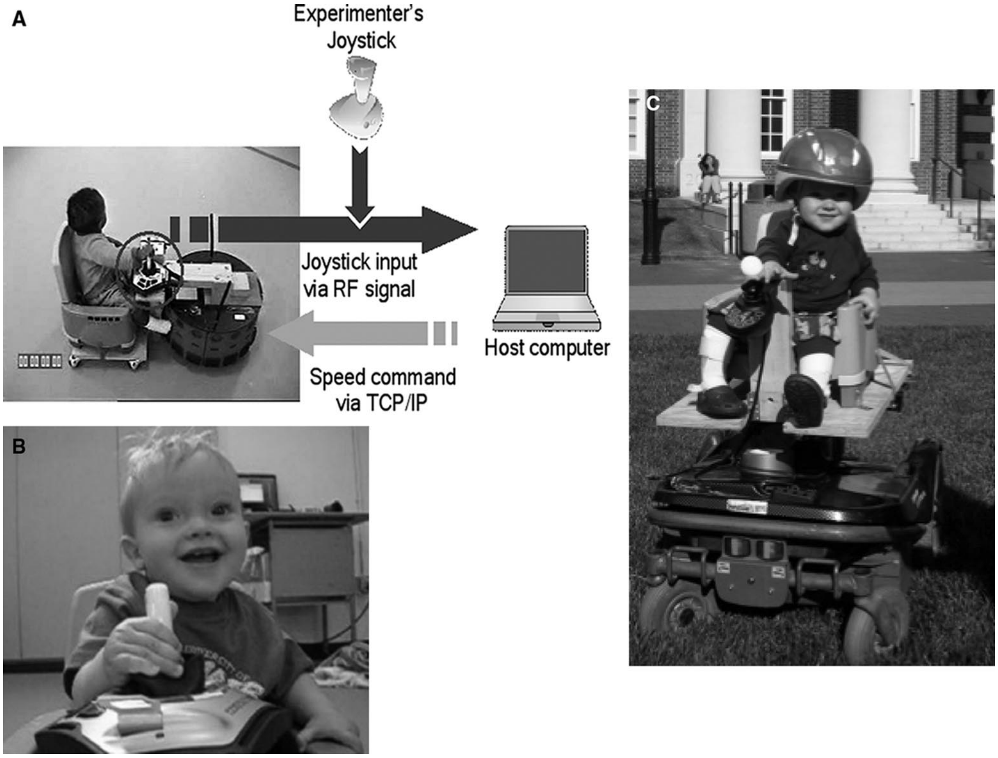

Fig. 1. A, UD1 is composed of a circular robot, wooden cart, baby seat, and modified joystick. Arrows display the information flow into the robot from host computer, and flow out of UD1's joystick and the experimenter joystick. B, The view from UD1's onboard camera. C, Andrew at 12 months of age driving a Permobil power wheelchair base fitted with infant seat during an outdoor training session.

lower extremity active range of motion and muscle performance. In sitting, he displayed full active range of motion of his upper extremities when provided external trunk support. In sitting without trunk support, he was able to reach upward to less than 45 degrees shoulder flexion unilaterally, using the opposite arm and a flexed trunk position for stability. With an adult stabilizing his trunk, he was able to lift relatively heavy toys overhead suggesting an upper extremity muscle performance of at least 4 of 5.

His lower extremity active range of motion and muscle performance presented with clear asymmetry with the right side more impaired than the left. Specifically, in supine, he showed left hip flexion to approximately 90 degrees, with no isolated active right hip flexion. He also showed limited antigravity knee flexion/extension in both legs, and full-active dorsiflexion movement of 5 to 10 degrees of his left foot with no movement noted in his right foot. His gross motor development was found to be 5 months at a chronological age of 6 months. He was pushing up on his elbows in the prone position, had good head control in the prone position to visually explore his environment, and demonstrated a consistent reach and grasp bilaterally. He was not sitting independently, pushing into quadruped position, or showing any independent floor mobility. The Bayley Scales of Infant and Toddler Development III[14] scores, from administration at 6 months of age before initiation of driving training and at 12 months at study completion, are listed in Table 1 and reported below in the context of changes in development during the power mobility-training period.

The specific requirements for our power mobility training were the ability to move the joystick and to maintain supported sitting in UD1 while interacting with experimenters and family. During the initial screening session, he met all these requirements. Given the risks for delayed or absent independent locomotion outlined above and the presence of reaching and sitting skills, he began training at 7 months of age. At study onset, there was no defined end criterion because we were unsure what progress he would make. We discussed with his mother that the training would end when the infant showed disinterest in driving. Ultimately, he continued training indoors for 4 months until he was 11 months of age, at which time he began showing frustration while driving UD1. As outlined below, we then modified an existing pediatric wheelchair and he resumed training indoors and outdoors with interest and enthusiasm.

TABLE 1

Pre-Training and Post-Training Bayley III Scaled, Composite, and Age-Equivalent Scores for Various Developmental Domains

	Scaled Score		Composite Score		Age Equivalent (Months: Days)	
Domains Evaluated	Pre	Post	Pre	Post	Pre	Post
Cognition	7	49	85	130	5:0	16:0
Language: receptive	11	16	100	106	6:0	14:0
Language: expressive	9	14			5:0	12:0
Fine motor	8	11	85	76	5:10	13:0
Gross motor	7	1			5:0	7:0

Note: Andrew was 6 months of age during Pre scoring and 12 months of age during Post scoring. Scaled scores provide a number reflecting rate of change, and thus it is possible for a lower scaled score in a post-test, as found in the gross motor domain.

Each session was structured into 2 periods occurring in series: Directional Driving trials and an Open Exploration period. Note that each of these periods functioned simultaneously as training experiences as well as assessment periods. That is, he gained driving experience during both periods and we were able to quantify his performance during both periods as well. We describe the dependent variables next. Then, in the Intervention section, we describe the rationale and procedures for the Directional Driving trials and the Open Exploration period, as well as UD1's onboard computer used for assessment.

The main goal of our assessment was to quantify the basic motion characteristics of UD1 while under his control throughout each session, and to quantify his success in driving to specific locations during the Directional Driving trials. To assess change in driving performance across time, we assessed dependent variables at monthly intervals, with onboard data processed from his best performance session within that week.

We used the onboard computer to capture 3 dependent variables including the following: number of joystick activations: the total number of joystick activations in which his grasp and pull action led to displacement of the joystick and UD1 movement. Each displacement is a "movement segment," with path length (meters): the average distance that UD1 traveled with each movement segment during both Directional Driving trials and Open Exploration within a given session, and total path length (meters): the total distance of path length of all movement segments across Directional Driving trials and Open Exploration within a given session. A customized Matlab program (Mathworks, 2007) allowed processing of onboard computer text data and analysis of driving performance data across developmental time. We also used UD1's onboard video camera to quantify the fourth dependent variable; percent-directed driving success, the number of successful trials during the Directional Driving trials as a percentage of total trials within 1 session. As noted below, the infant participated in straight and right/left directional trials. A successful trial was when he drove within 1 foot of the experimenter or mom, released the joystick, and grasped the toy. A primary coder evaluated the video of sessions to score successful trials. This coder's performance was directly compared with that of a second coder, who was naïve to group assignment. Each coder scored trials during separate sessions. The two coders' performance was compared during 4 sessions (total of 31 trials). Interrater reliability was calculated as number of agreements between coders in scoring a successful trial as percent of total trials. There was 100% agreement between coders. In addition to driving performance variables, the same experimenter (A.L.) who provided training also quantified the infant's general development as reflected by the Bayley Scales of Infant and Toddler Development III.[14] His developmental age in the cognitive, language, and motor subtests of the Bayley III was determined both pretraining and posttraining and was compared with his chronological age.

DESCRIPTION OF INTERVENTION

Device

Our power mobility device (UD1, shown in Figure 1A) was a joystick-driven iRobot's MagellanPro robot (iRobot Corporation, Bedford, MA) with a commercial infant booster seat that was mounted on a frame and attached to the robot (Safety 1st, Columbus, IN). Further information on the device can also be found in our prior publication.[11] We calculated 2D linear position of the robot, with the resultant change in coordinates yielding path trajectory, length, and speed as described earlier. A small camera (Cool Pix; Nikon, Inc. Tokyo, Japan) mounted on UD1 was used to collect video of the infant's head, hands, and UD1's joystick at 30 Hz (Fig. 1B). The video images enabled coding of "percent driving success" as described earlier.

Training Protocol

The child participated in training 3 to 4 times per week from 7 to 12 months of age. Training consisted of experiences gained from the Directional Driving trials and the Open Exploration period. This 2-period protocol was based on both the general experiences provided to infants during the emergence of independent mobility, and our clinical and research experiences working with young infants including early power mobility training.[11] In typical development, infants spend time with caregivers working on "directional" movement, such as when a caregiver encourages an infant to "crawl to me," and also significant time in which they direct their own movement via "open exploration" of their environment.

The goal of each session was to simultaneously provide infant-friendly training as well as a standardized quantitative assessment. At the start of each session, the infant was seated and secured in UD1, in a standard location within the 12 × 20-ft room. The room was a subsection of a large gymnasium within the University of Delaware Early Learning Center, a center with child care and research facilities.

In Directional Driving trials, he was provided with 5 trials to drive straight for 6 ft to retrieve a toy from the experimenter or his mom. If he was successful in 3 or more of the 5 trials, he advanced to attempt 5 trials driving 6 ft alternatively to right and left locations. At the start of each trial, he was shown a toy within reaching distance to gain his interest. The experimenter or his mother then moved to the end location and encouraged him to drive. A standardized prompt protocol was required especially during the initial training sessions when the infant did not reach to contact the joystick. The prompt protocol was a series of 4 cues at 30-second intervals of increasing adult interactions that started if he did not begin driving. The first cue was the initial driving prompt in which the infant was shown the toy within reaching distance, followed by adult touching the joystick and a verbal "come get me." After the first 30 seconds, the adult touched the joystick with a verbal "get your stick." The prompt series then progressed to the adult touching the infant's hand and the joystick, and finally to directly put the infant's hand on the joystick. Each of the latter prompts also included encouragement to get the joystick and move to the adult. If, after a 2-minute prompt cycle, he did not drive greater than half the distance, the trial ended. He was then driven, by the experimenter, to the destination location, praised for getting to the toy, and then driven back to start location for the next trial. For a demonstration, see the online video, available at http://links.lww.com/PPT/A2.

In the Open Exploration period, the infant was provided up to 20 minutes of unrestricted exploration of the training space. The experimenter or his mom often stood at a distance with a toy or other interesting object to encourage continued exploration. The experimenter also ensured his safety by using the second joystick to redirect UD1 whenever he closely approached a wall. However, the driving space was free of obstacles during Directional Driving trials, soft mats, and other objects are placed around the room to motivate him and allow physical negotiation and interaction with the environment. Open Exploration ended with inconsolable crying or 2 consecutive minutes of no driving. Note that the small movement segments in which the experimenter drove UD1 during Directional Driving trials or Open Exploration were removed in data processing.

Other Interventions

The power mobility training was not a substitute for other early intervention services, and the infant's family was encouraged to continue all medical appointments and therapy sessions during the training period. The infant initially received physical therapy on a weekly basis, then increased to 2 times per week in training month 3. His therapy team and family focused on gross motor abilities with and without assistive equipment. He also received a rolling prone stander in training month 3.

DESCRIPTION OF OUTCOMES

The infant improved across the training period in all dependent measures. For driving performance variables, the first data point is performance on day 1, whereas the remaining data points reflect performance at 30-day intervals across the 4-month training period. Outcomes reflect the sum onboard driving performance across both Directional Driving trials and the Open Exploration period for joystick activations, path length, and total distance driven. Driving success reflects only driving performance during the Directional Driving trials.

Joystick Activations

He nearly doubled the frequency of joystick activations from baseline to training month 4 with a noted increase between months 2 and 3 of training (Fig. 2A).

Path Length (Meters)

He steadily increased his ability to sustain joystick activation for greater amounts of time leading to moving a longer distance with each joystick activation (Fig. 2B).

Total Path Length (Meters)

He increased the distance UD1 moved, more than doubling his total distance traveled within a session from baseline to training month 4 (Fig. 2C).

Percent-Directed Driving Success

His success during the Directional Driving trials steadily increased across the training period (Fig. 2D). Specifically, by the last week of training, the vast majority of driving trials were successful in directional efforts to drive to a desired goal, whereas he had no successful trials at baseline. After 4 months of training, driving trials were less variable, more frequent, and more successful.

Although his driving performance consistently increased over the months of training, during training month 4 he became frustrated with the Directional Driving trials that required him to drive left or right to retrieve a toy. Thus, in month 5, we retrofitted an existing, commercial pediatric power wheelchair (Permobil, Entra, Lebanon, TN) with an infant seat to allow him to drive indoors and throughout the Early Learning Center's large outdoors playgrounds. His frustration significantly decreased, and after 3 days of training in the power wheelchair, he drove straight across a greater number of trials (10 trials) with greater percent success than in any previous month of training (Note the column labeled "Wheelchair" in Figure 2D Goal-oriented Driving). He did not gain control of right or left directional driving during the training period. For demonstrations, see the online videos, available at http://links.lww.com/PPT/A3 and http://links.lww.com/PPT/A4.

Bayley III

The Bayley III[14] was administered pretraining and post-training to evaluate general developmental performance. As expected, his scaled and composite scores reflected developmental progression in cognition, language, and fine motor skills (Table 1). Interestingly, his Bayley age-equivalent scores, which provide a general age of development, far exceeded his chronological age by the end of the training period. Specifically, during pretraining, when he was 7 months of age, his age-equivalent scores ranged from 5 to 6 months of age. By the end of training, when he was 12 months of age, his age-equivalent scores for expressive language and fine motor matched his chronological age. Most notably, his cognition and receptive language exceeded his chronological age by 2 to 4 months, suggesting that his developmental rate was somewhat accelerated in these domains.

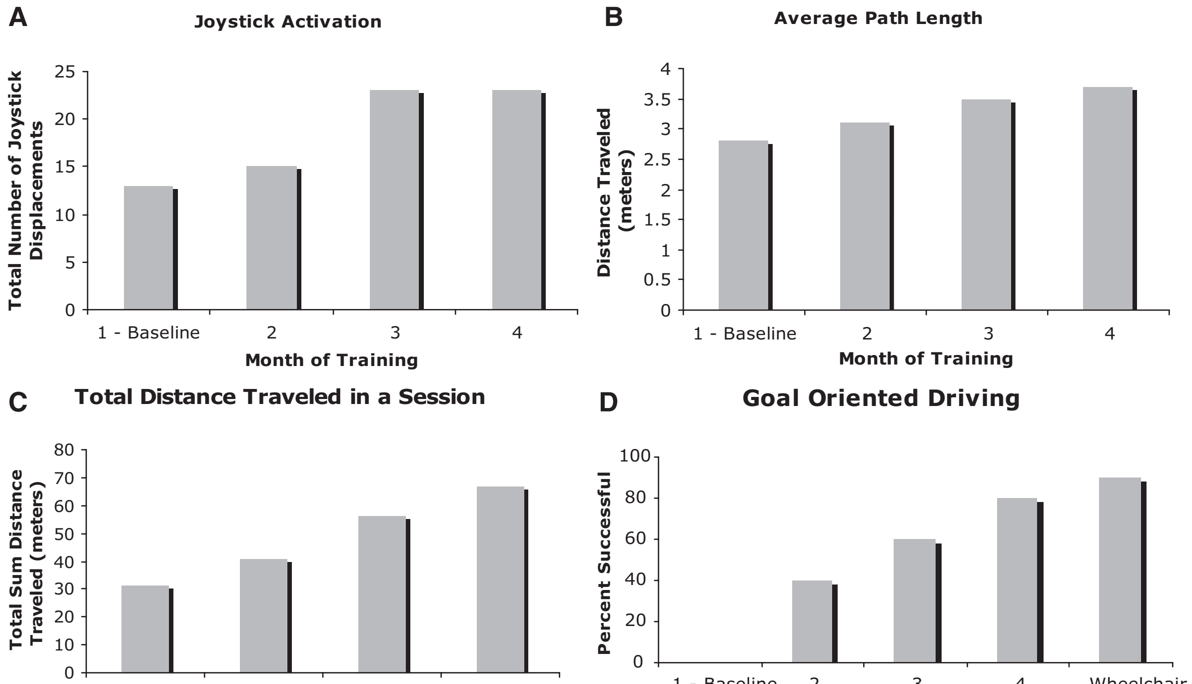

Fig. 2. The infant increased the frequency of joystick activations (A, joystick activation), increased the average distance per joystick activation (B, path length), traveled greater distances within a session (C, total distance traveled), and had a greater driving success rate (D, goal-oriented driving) across the training period.

DISCUSSION

The focus of this report is an infant with a medical diagnosis of lumbar myelomeningocele associated with significant motor impairments that typically limit the emergence of independent crawling and walking. His lack of typical mobility at 7 months of age, his risks of future immobility and mobility-related impairments in development, his ability to tolerate periods of supported sitting, and his functional upper extremities made him a good candidate for power mobility training.

This study demonstrated a young infant's ability to activate a joystick, not only to achieve motion in an experimental power mobility device but also to increase his driving performance. This study joins other work suggesting a positive effect of power mobility in young children.[15] Moreover, this report provides the first comprehensive quantification of a standardized power mobility training protocol in an infant with special needs younger than 1 year of age. Technologically, this report also introduces the application of an onboard computer system, which allows the quantification of driving performance data for research and clinical documentation. Finally, this report fits well with the recent position statement by the Rehabilitation Engineering and Assistive Technology Society of North America on early power mobility training,[16] and the increasing focus on toddler-appropriate power wheelchairs by manufacturers as evidenced by the Wizzybug (Bath Institute of Medical Engineering, Royal United Hospital, Bath, United Kingdom), the Snapdragon (Dragonmobility, Cambridge, United Kingdom), and the K300 PS Junior (Permobil, Lebanon, TN).

Pediatric Power Mobility Training

Although this is not the first study of early power mobility training, this case report is the first to quantify the feasibility of a training program in the young infant. In one of the first studies, 2- to 3-year-old children with physical disabilities, such as cerebral palsy, provided unstructured training learned the cause-effect relationship that joystick motion causes chair motion and increased their driving time.[6] Unstructured training also had a positive effect on socialization skills, overall daily living, and driving performance in adults with profound mental disabilities.[17] Most recently and most directly related to this work, 6 months of daily unstructured training led to functional driving abilities and to increased socialization in a 20-month-old child with type 1 spinal muscular atrophy.[15] In addition, although the child had the device for 6 months, her rate of development exceeded calendar time, with a 7-month gain in cognition skills and a 13-month gain in communication skills during the 6-month period. Similar to the finding of Jones et al,[15] the infant in our study attained developmental skills at a faster rate than he aged for all domains except gross motor. The developmental rate of change that he exhibited may be atypical for children with spina bifida compared with recently reported developmental trends.[18,19]

In summary, this case report has 2 key clinical implications that require further study. First, a progressive, standardized training and assessment protocol with consistency in driving opportunity time, direction, and cueing may be feasible in early infancy for certain pediatric populations. Second, technology is available that allows the quantification of driving performance without resorting to the controlled environment of a laboratory. It is important to note that this case report has limited generalizability to other pediatric populations and can only suggest associations between training, driving performance, and development. Based on this single case report, we suggest 3 directions for future research. First, power mobility devices for young infants are needed. In recent focus groups with local providers, we found that a primary reason for not considering power mobility earlier is lack of available power devices with seating systems to accommodate infants. This case report provides an example of both an experimental device as well as the retrofitting of existing equipment. Second, quantification of the group effect of training on driving performance and development is needed. Mobility devices similar to ours offer the potential to gather laboratory grade data on meaningful measures in the clinic. Third, this study challenges the clinical rationale for delaying the power mobility training until a child demonstrates particular cognitive, spatial, and/or movement abilities. Our findings support the recent position by the Rehabilitation Engineering and Assistive Technology Society of North America that "age should not eliminate the child as a candidate for power mobility."[16]

To be clear, we are not suggesting that early power mobility replace the potential for equipment-assisted upright ambulation. Rather, we suggest the utilization of early power mobility as a means for exploration and learning that may affect later perceptual, cognitive, social, and quality of life outcomes. We believe that there is sufficient support to begin group studies that address the efficacy of early power mobility training programs and the design and construction of power mobility devices for infants.

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