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Modified Ride-on Toy Cars for Early Power Mobility: A Technical Report

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Abstract

Background and Purpose—Children with significantly decreased mobility have limited opportunities to explore their physical and social environment. A variety of assistive technologies are available to increase mobility, however no single device provides the level of functional mobility that typically developing children enjoy. The purpose of this technical report is to formally introduce a new power mobility option - the modified ride-on toy car.

Key Points—This report will provide a) an overview of toy car features, b) examples of basic electrical and mechanical modifications and c) a brief clinical case.

Clinical Implications—With creative use and customized modifications, toy cars function as a "general learning environment" for use in the clinic, home and school. As such, we anticipate that these cars will become a multi-use clinical tool to address not only mobility goals but also goals involving body function and structure such as posture and movement impairments.

Keywords

assistive devices; child; child/preschool; child development; equipment; motor skills; mobility limitation; physical therapy modalities/instrumentation; toys; wheelchairs

Introduction

Children with neuromusculoskeletal impairments that significantly decrease their mobility have limited opportunities to explore their physical and social environment.[1,2] As such, they are at risk of for secondary cognitive, social and emotional impairments.[2] Assistive technology (AT) offer a means of independent mobility[3–7] which in turn can improve spatial awareness skills, eye-hand coordination, visual perceptual skills, spontaneous vocalizations, initiation of contact and meaningful interaction with others, and motivation to explore.[4,5,8–11]

Pediatric therapists have a variety of AT available to increase mobility, including strollers, walkers, adapted tricycles, self-propelled standers, manual and power wheelchairs.[6,11,12] As with any AT, these mobility devices have limitations[3,13] and currently no single device provides for the level of functional mobility across the multiple environments that children

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who are typically developing enjoy. The introduction of new mobility devices help expand the choices that clinicians, families and children have to maximize mobility.

Our previous work and that of others suggests that pediatric power wheelchairs[8,9,14–17] and experimental robot enhanced mobility devices[15–19] are feasible even for children under 2 years of age. This ‘early’ power mobility training is of interest as it may have a significant effect on cognitive and social development. Unfortunately, pediatric power chairs have features that limit their functional use in the community.[6,12,20] These include their size, weight, cost, accessibility, ease of transportation, maintenance requirements and social acceptance.[5,13,20] Environmental limitations, such as when a power chair is used in a small space in the home for example, have been cited as particularly limiting to functional use.[13] Specifically, although caregivers reported that more than 90% of children wanted to use their power chair inside and outside their home, only half of these children were able to do so. Loading a power chair into a vehicle can be physically difficult, time consuming and requires an adequately sized vehicle. Only 57% of 35 caregivers[13] had a van for transportation. Experimental mobility devices have the potential to address some of these limitations such as size, weight and cost but are likely years from commerical availability. It is critical to identify AT that is available at this time for use by children and their families to address activity and participation goals.

The purpose of this technical report is to formally introduce a new option for early power mobility – the ride-on toy car. This report will provide a) an overview of toy car features, b) examples of basic electrical and mechanical modifications to seating, steering systems and drive systems, and c) a brief clinical case.

Ride-on toy cars: General Features

Table 1 briefly summarizes the basic features of toy cars. Four features are of particular interest: cost, accessibility, aesthetics and adjustability. First, toy cars cost less than $400 and often under $200, which is comparable to or less than most mobility devices. Second, most are relatively light weight, small and often can be easily transported unlike power chairs. Third, the child-friendly, colorful toy designs and the various toy functions (e.g., headlights, radio, car noise) likely make these cars more acceptable to adults and children than some other mobility devices. This may be an important aspect for clinicians wanting to start early power mobility training with families hesitant to discuss power chair options. Fourth, a toy car is not a complex electro-machanical device and, as outlined below, can be modified quickly and easily with a range of customized accessories that match the child’s changing capabilities and family goals.

Ride-on toy cars: Modifications

Toy cars will likely require electrical and/or mechanical modifications for use with children with mobility impairments.[21] Two interesting aspects of modifying these cars are 1) modifications can be constructed to be permanent (i.e., relatively fixed) or temporary (i.e., interchangeable), and 2) with creative design and planning, clinicians can construct a range of custom modifications to address goals reflecting 1 or more of the International Classification of Functioning, Disability and Health (ICF) components[22] while the child and family focus on fun.

Initially a decision must be made regarding which of the various car types and sizes fit a child's current and/or future body size and capabilities (Figure 1). Cars can be purchased in most major stores carrying toys or ordered online from distributors worldwide. Each toy car has an original design with features that inherently fit certain children. Thus, the type and degree of modification of that original design becomes child and goal specific. For example, the original design of a Fisher Price Lightening McQueen ™ (Fisher-Price Headquarters, East Aurora, NY) may fit a taller or larger child than a Fisher Price 'Mater ™ (Fisher-Price Headquarters, East Aurora, NY) given the greater leg room. The McQueen however will require more seating modifications for children with less trunk control than 'Mater (Figure 1a & 1b). The original design of a Fisher Price Thomas Train ™ (Fisher-Price Headquarters, East Aurora, NY) may fit a child with small body size and good trunk control given its small seat size and minimal seat supports (Figure 1c & 1d). Two-seat cars (Fisher-Price Headquarters, East Aurora, NY) can also be used if a child has a larger body size, wants to drive with siblings and peers, or needs a place for additional equipment such as a ventilator (1e &1f).

Next we introduce a few basic modifications involving a) seating, b) steering systems and c) the drive system. These modification examples were specifically chosen as they were simple, low cost and appropriate for clinicians and/or families to undertake. These modifications use readily available materials including PVC pipes, carriage nuts and bolts, pipe insulation foam, Velcro, commercial switches, electrical wire and wire connecters. The total cost of these modifications was less than $150 per car. Appendix I (available online as Supplemental Digital Content 1, http://links.lww.com/PPT/A28) provides a sample hardware list.

Seating

Traditionally, a modified seating system should augment a child's postural control such that she can efficiently function. For the toy car, one function may be to activate the steering and drive systems. In addition, to providing rigid support, various permanent and temporary seating modifications allow clinicians to address one or more ICF components – even within the same session. Conceptually, tighter or more extensive trunk support may help a child to reach the steering wheel and grasp toys during car movement to address an activity or participation goal. By loosening or lessening the trunk support modifications in combination with a basic drive system (e.g., pressing large switch), clinicians address ICF body functions and structure goals by providing a challenging, dynamic postural control task during driving. This highlights how creative design can extend the use of a toy car into the realm of "therapeutic tool" for more general assessment and/or treatment.

Specific examples of permanent seating modifications include a roll cage, a seat belt and hip strap. A basic roll cage can be built from connecting different lengths of PVC pipes mounted around the car frame (Figure 2a). Seat belts and/or hip straps can be constructed from an off-the-shelf product (see 'Walking Wing' in Appendix I, http://links.lww.com/PPT/A28) and/or Velcro (Figure 2b). Both function similar to a roll cage for stability and safety. Specific examples of temporary modifications include a T-bar, a seat or back cushions, body side-supports and head supports. A T-bar constructed of PVC pipes can limit lower extremity adduction and excessive forward trunk motion (Figure 2c). Cushions, trunk supports (Figure 2d) and head supports constructed of foam sheets, towels and/or pipe insulation foam can be adjusted, removed or replaced within minutes to address various ICF component goals within a session while maintaining the child's motivation to drive.

Steering and Drive Systems

As with seating systems, modified steering and drive systems should accommodate each child's current and/or future capabilities, interests and session goals, and can be permanent or temporary. The drive system refers to the means by which power is delivered to the wheels. Standard drive system includes a gearbox in the rear wheels. Modifications of the steering and drive system can be made separately but are often considered in combination. A useful permanent modification of the drive system without involving the steering is to install an on-off power switch (Figure 3a). A Toggle switch can be connected with one of the wires coming from the car to control the power. See Appendix II available online as Supplement Digital Content 2, http://links.lww.com/PPT/A29, for specifics.

Basic steering-drive system options include a round steering wheel (Figure 3b) with push-button switches of various sizes and a bar handle style with different sizes of PVC pipe (Figure 3c). A bar handle-small push-button switch combination may be easier for children with functional upper extremities (UE) and thus allow other body function, activity and/or participation goals to be addressed without the child having to focus on a challenging steering and drive system. For children with UE impairments, this same modification will present a challenge and thus can be used to focus directly on UE goals. In contrast, a steering wheel covered with a large push-button switch decreases the focus on the steering and drive system, and allows successful mobility. Switches with vibration, light and music may further enhance the attention and motivation of children with lower response levels. The adaption of a Phono Plug Y-adapter cable is a useful connecter for steering-drive system modifications. After connecting the wires of the toy car to the adapter cable (Figure 3d), various push-button switches can be plugged into the connector directly allowing the use of various steering systems (Figure 3e).

More complicated steering-drive system modifications can be constructed such as to create a ‘standing car’ to address mobility goals as well as body functions and structure goals involving bone and muscle strength, and dynamic balance. A Fisher Price Quad™ (Fisher-Price Headquarters, East Aurora, NY) for example can be modified to be driven while standing by installing a 2-tiered handle bar steering system with PVC pipes and modifying the drive system to encourage standing by reversing the wiring of a push-button switch placed on the seat (Figure 3f & 3g). An example of an advanced steering-drive system modification requiring an electrical expert would be the electrical and mechanical connection of a joystick for use on a remote-controlled (R/C) ride-on car (Figure 3h) (ZP Toys, 1 Floor Khairani Road Sakinaka, Andheri (E), Andheri East, Mumbai). R/C cars allow either the child or an adult to drive the car via separate controls. We anticipate more toy cars with R/C circuitry in the future, which should further expand the interfaces used to drive, such as head arrays, and thus expand the number of children that can drive these toys. Using more complex interfaces will require more complex modifications to the driving and/or steering system. This should not be a deterrent to clinicians given the significant benefits of independent mobility and the opportunity to address body functions and structure goals. It is important to note that these types of advanced electrical modifications should be inspected by if not completed by an electrical expert.

Clinical applications

The following is a brief clinical case to illustrate customized seating, steering and drive system modifications. This case also highlights the ability to ‘trial and error’ different types of cars and modifications. This project was reviewed and approved by the institutional review board. Written parental permissions giving informed consent for their children to participate were obtained before participation. This case involved a 28-month old girl whose diagnosis was cerebral palsy with spastic quadriplegia. Her upper and lower extremity functions were classified as a Level III by the Manual Ability Classification System (MACS) [23] and a Level IV Gross Motor Function Classification System (GMFCS). [24] Initially, we fit her into 2 styles of small toy cars (Fisher Price Quad. and Mater) with the Mater chosen due to its original seat design providing her a level of trunk support (Figure 4a). The initial seat, steering and drive system modifications, based on the child’s capability and group discussion, included a roll cage, safety belt and hip strap, T-bar, cushion, on-off power switch and a bike handle with a small, pushbutton switch mounted on the left side

(Figure 4b). During her initial driving sessions, we noted that the bike handle/push-button to trunk distance was too great and required an awkward lean. Activating the switch was too challenging due to insufficient finger control. Given these limitations and the initial focus on activity goals of mobility in her home, we proceeded with a 2nd design. Specifically, we modified the handle shape, and installed a larger, more sensitive switch on the left side (Figure 4c). With additional driving experience, we noted that the size of the handle bar and T-bar was too large and and too close to her body, which made her upper trunk lean backward while driving. In the 3rd design, we altered the size of the PVC pipe and lowered the handle bar and T-bar height. To provide more upright posture and stability, the family added extra padding to the seating system, and used fabric to cover the supports (Figure 4d). As a result of these multiple modification cycles, the child could activate the switch independently and drive with a comfortable, upright posture (Figure 4e). Arriving at an optimal toy car (Figure 4f & 4g) is likely to require several stages of permanent and temporary modifications as well as several stages of training.

Special considerations

Limitations and Safety Issues

Toy cars can provide opportunities for independent mobility; however current designs have important limitations that must be considered. First, most toy cars have a turning radius that is relatively large for functional indoor driving. Second, in order to turn while driving, a certain level of UE function is needed to control the steering system. A modified joystick steering and drive system may help a child with moderate or severe motor impairments learn to turn while driving. Third, as with other wheeled mobility devices, do not currently allow clinicians to address walking and may not be easy for children to get lower extremity goals and are not easy for most children to get into and out of independently.

All modifications presented in this paper were inspected by engineers to ensure the child's safety. Although mobility and exploration are critical goals, wheeled devices such as power chairs are designed to improve mobility and exploration is a critical goal in early intervention, wheeled devices such as power chairs and toy cars are not meant to drive on all surfaces. [25] Driving over stairs, curbs and rough terrain and driving into objects can result in serious injury. As a result, home modifications are often necessary and close supervision is always recommended.

Conclusion

Clinicians and families are confronted with the challenge of determining when a child is appropriate for power mobility training, and which devices fit current and future goals.[26,27] Toy cars can be used in the clinic, home or school to improve independent mobility and are a low cost alternative or addition to other mobility devices. In addition, they provide a novel therapeutic tool to examine and/or treat body function level impairments such as cause-effect learning, and head-UE, trunk-LE strength and control. Given this flexibility of use, the toy car might be best considered a 'learning environment' in which to challenge a child while maintaining a high level of motivation and fun through mobility and play. One future direction to be considered is to use these 'low tech' toy cars as a platform to place additional technology such as communication devices and more complex seating, steering and drive systems to allow a wider range of children to drive. We also hope future interest in modified toy cars will influence the power chair industry to consider plastic-based power chair designs as a commercially viable product for children under 3 years of age.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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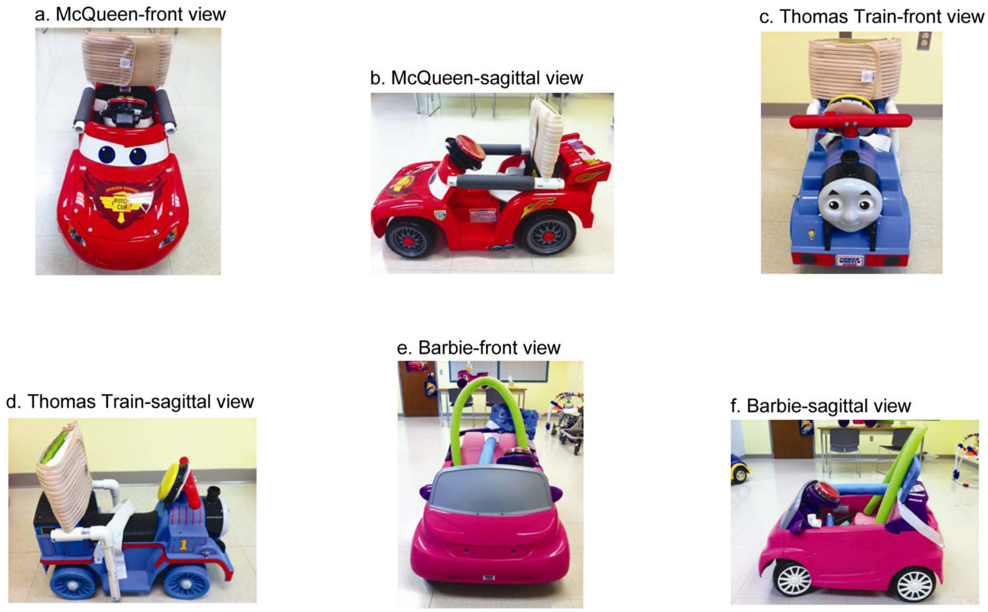

Figure 1.

Different modifications and cars. All cars are made from Fisher-Price, Inc. toy cars (Fisher-Price® Power Wheels®, Fisher-Price Headquarters, East Aurora, NY).

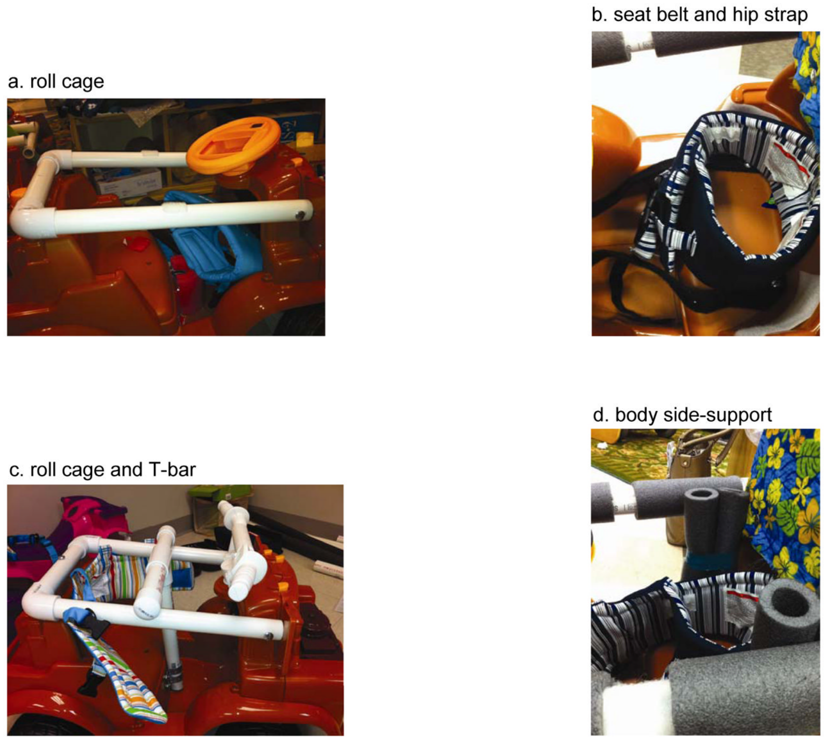

Figure 2.
Modifications of seating system

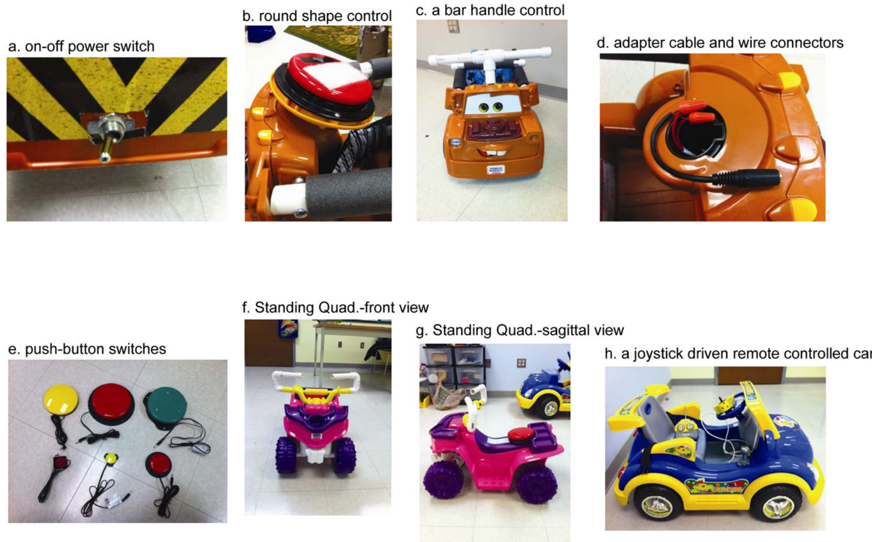

Figure 3.

Modifications of steering and drive system. All cars are made from Fisher-Price, Inc. toy cars (Fisher-Price® Power Wheels®, Fisher-Price Headquarters, East Aurora, NY), except for (h) the remote controlled one (ZP Toys, 1 Floor Khairani Road Sakinaka, Andheri (E), Andheri East, Mumbai)

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Figure 4.
Clinical applications

Table 1

Technical overview of features of ride-on toy cars

	Small	**Large**
Availability	hundreds of models worldwide	hundreds of models worldwide
Age (years)	1–3	3–6
Price (USD)	70–150	200–>400
Weight (lbs)	< 24	70–130
Speed (mph)	2, 2.5, 3.5 (typically one speed)	2.5, 3.5, 5 (typically one speed)
Seating Capacity	1 passengers	2–4 passengers
Wheels	3 or 4	3 or 4
Terrain	indoor and outdoor, flat	outdoor, flat and hills
Styles	cars, trains, jeeps, tanks, motorcycles, farm vehicles	cars, jeeps, tanks, motorcycles, scooters
Designs and Frame options	colorful, cartoon characters with plastic frame	colorful, cartoon characters with plastic frame
Battery/Drive	6v/single gear box	12v/dual gear box
Noise Level	minimally distracting	potentially distracting
Activation	push-button, pedal button	push-button, pedal button, remote controller
Transportation	any type of car	CRV, mini-van, van
Maintenance	keep clean, regular check of battery power	keep clean, regular check of battery power
Focused on ICF Components	body functions and structure activity participation	body functions and structure activity participation

*Abbreviations: mph: miles per hour; CRV: compact recreational vehicle; ICF: International Classification of Functioning, Disability and Health