Quantifying toddler exploration in seated and standing postures with powered mobility

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INTRODUCTION

For many infants and toddlers with mobility disabilities, access to developmentally appropriate mobility technology is crucial to facilitate self-initiated movement, exploration, and social engagement. Delayed early mobility (i.e., 2-4 years later than nondisabled peers) can initiate a cascade of effects such that toddlers with disabilities fall behind their peers across multiple developmental domains [1]. New technology is expanding powered mobility access and options for very young children with disabilities [2, 3]. The Permobil Explorer Mini, released in 2020, is the first FDA-cleared pediatric mobility device available in the US specifically designed for children 12-36 months old. The joystick-controlled device has a 360° turn radius, runs on a 12V battery, is lightweight (52 pounds), and has adjustable speeds with a maximum of 1.5 mph. One prior study with 33 toddlers with a variety of diagnoses (e.g., cerebral palsy, spina bifida, down syndrome, developmental delay) qualitatively described the initial driving and emotional experience when using the Explorer Mini [3], They found that 94% of the toddlers were able to move the Explorer Mini within two 15-min driving sessions.

An additional unique feature of the Explorer Mini is that the seating configuration is adjustable and can be used in both a seated and standing posture. This option may allow the child to simultaneously work on rehabilitative goals while exploring mobility and engaging in socialization with peers and family. Offering the option to stand may potentially support development of muscle activation and coordination, balance, head and trunk stability, or transition to ambulation, but driving in the standing posture in the Explorer Mini has yet to be empirically evaluated. Logan et al. demonstrated feasibility and potential of standing powered mobility with a modified ride-on car that activated when a child stands. Their case study found that the child participated in less solitary play and more peer interaction with the ride-on car compared to his standard form of mobility with forearm crutches [4]. While data is forthcoming from one additional clinical trial led by our research group that compared developmental outcomes, use patterns, and caregiver perceptions of the Explorer Mini and a modified ride-on car [5], to our knowledge, no studies have yet evaluated the impacts of seated or standing postures on powered mobility use and child engagement.

Evaluating early device use with seated and standing postures may also provide crucial evidence to support a multimodal mobility approach to early intervention that incorporates physical therapy and powered mobility. Many clinicians still express hesitancy with incorporating powered mobility as part of an early intervention program due to misconceptions that it might interfere with gross motor skill acquisition, such as walking [1, 6, 7]. In one study in Canada, many occupational and physical therapists view early introduction of power mobility positively for children with mobility limitations; however very few of these therapists actively provide power mobility experiences [8].

One key challenge of deploying early powered mobility is the lack of knowledge on the physiological impacts of use. Expanding and improving the evidence of the impacts and use patterns of toddlers using powered mobility is critical to further expand the acceptance and use of powered mobility for this population. Quantifying and understanding device use (i.e., navigation and movement patterns) and the neuromechanics of how a child explores and learns to use powered mobility devices represent critical gaps in our knowledge to inform design and deployment. The purpose of this study was to quantify toddler exploration in both seated and standing postures while using the Explorer Mini by investigating how they learn to activate the joystick and navigate through space. This work will provide the first quantitative data on the effects of seated and standing powered mobility in toddlers with disabilities informing the application and use of early powered mobility; hopefully, helping close the gap of self-initiated mobility with their nondisabled peers.

METHODS

Six children (age: 20.2±5.2 months, 4M/2F) (Table 1) and their parent(s) participated in 4 visits where they drove the Explorer Mini in an enriched play environment in seated and standing postures. The Explorer Mini saddle seat and tray height were changed so the knees were bent at a 90-degree angle in a seated posture and when in the standing posture, the knees were straightened, and the feet were more under the hips (Figure 1). The saddle seat was left in place as support in both postures. Each visit consisted of two 15-minute play sessions, one each in seated and standing postures. The play sessions were child-led and guided by the Assessment of Learning Powered mobility use (ALP) tool facilitating strategies [9]. We developed and deployed a custom sensor-suite that integrates with the Explorer Mini and included joystick tracking, wheel encoders to accurately calculate speed and distance traveled, and four compact compression load cells to measure loading from the child's legs on the device footplate. Primary outcome measures were total distance traveled, duration of each bout, the number of bouts, and percent bodyweight support. A driving bout was calculated using the joystick position, one bout is defined as the joystick being moved away from the neutral position until it was released and returned to the neutral position. We normalized the amount of force being put through the participants legs to the device base by each participant's weight to calculate percent bodyweight support.

Figure 1. Comparison of seated and standing postures. Note the saddle is present in both postures.

Table 1. Participant Characteristics

Participant ID	Age (months)	Sex	Weight (kg)	Disability type	Mobility at study entry
P01	14	M	9.9	Neurological	Sitting
P02	16	M	10.1	Orthopedic	Cruising
P03	21	M	8.7	Neurological	Sitting
P04	24	F	9.9	Neurological	Walking
P05	28	M	10.7	Cerebral palsy	Rolling
P06	18	F	11.3	Cerebral palsy	Rolling

RESULTS

All six participants engaged with the joystick in their first play session and learned to move along a forward path, successfully completed driving sessions in both seated and standing positions. All participants engaged in both exploratory and goal-directed driving.

Driving and navigation metrics

Across all 15-minute seated and standing play sessions, the participants traveled between 2.4 and 190.0 meters (Range) and activated the joystick an average of 658 times (Range: 103-1305). The average time of each joystick activation was 0.7 seconds. Of these activations, 93% were short bursts of less than 1 second, with only 4% of joystick activations being greater than 2 seconds and only 2% of joystick activations being greater than 5 seconds. The longest joystick activations ranged between 36 and 266 seconds, which often corresponded to periods where they were spinning in circles or continuously driving. Primary joystick activation direction was different for each participant. For P03 (28%), P05 (37%), and P06 (29%) the most common direction was backward, while P01 (57%), P02 (30%), and P04 (30%) primarily drove forward.

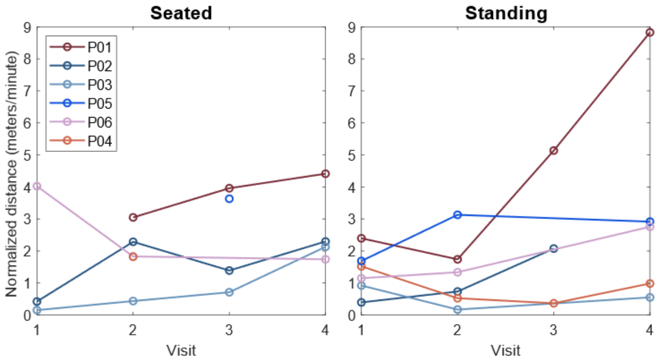

Figure 2. Distance traveled each session separated by body position with sit (left) and standing (right).

Comparison of seated and standing postures

<u>Driving and navigation</u>

On average, participants drove shorter distances in the standing posture (1.96 m per minute) than in the seated posture (2.14 m per minute) (Figure 3). However, the average number of driving bouts in standing was 187%

greater compared to the seated sessions. Only one of the six participants (P03) had the opposite trend in which they had 55% more activations in their seated sessions when compared to standing sessions. There was no significant difference between mean activation duration between seated and standing (p=0.1). Participants spent 28% and 22% of the time driving vs. stationary time in the seated and standing sessions, respectively.

<u>Bodyweight support</u>

The average loading through the base of the device was 12.5% and 10.7% of bodyweight for seated and standing sessions, respectively. The average maximum loading through the base of the device was 52.3% and 48.3% of bodyweight for seated and standing sessions, respectively.

DISCUSSION AND CONCLUSIONS

Participants were all able to interact with the joystick, with a majority of driving bouts being less than 1 second long. The participants primary joystick activation direction was split into two groups, half preferred forward, and the other half preferred backward. This preference in direction may relate to motor control and which motion was easiest to control the joystick instead of a preference in driving direction. When in the standing posture, participants drove shorter distances per session and more bouts.

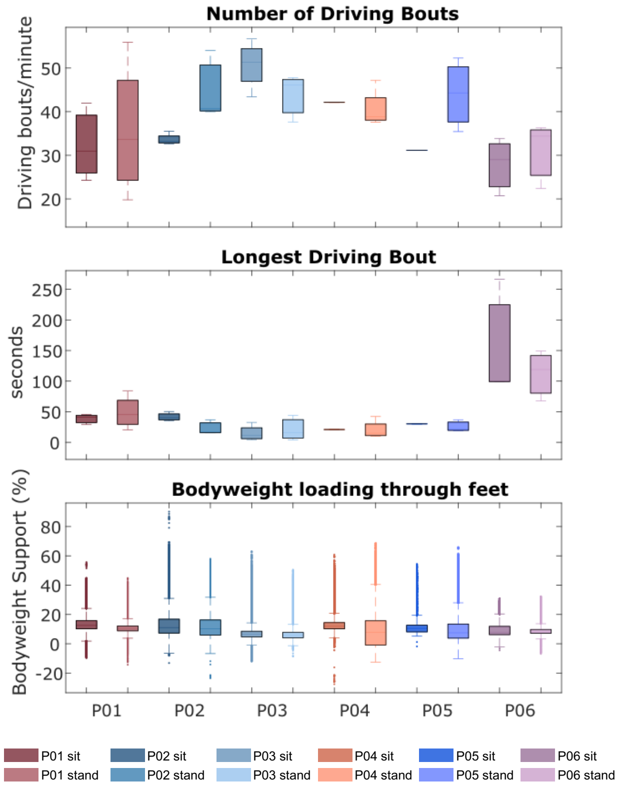

Figure 3. Navigation and bodyweight support differences in seated and standing posture.

Participants supported a similar percentage of their bodyweight in both seated and standing postures. Due to the design and positioning in the seated and standing postures, there was loading through the children's feet in both postures. This finding suggests that the seated and standing postures in the Explorer Mini mainly influence leg positioning, not loading, and that children continued to put a large proportion of the bodyweight through the saddle seat in both postures.

These results show the feasibility of short bouts of exposure (15–20-minute play sessions) to powered mobility as an effective roadmap to translation into clinical settings to provide access to powered mobility for toddlers. This can help embolden clinicians who may philosophically believe in the benefit of powered mobility for this age group but do not currently incorporate it into their clinical practice. Children do not require extensive training and time in a powered mobility device to learn how to use it to explore and engage with their surroundings.

One of the challenges with working with young children with disabilities is the inherent variability. Since this has never been done before, we chose to include a wide variety of disabilities and focused on exploratory play for child comfort and engagement. Sessions were structured based on the tolerance and interest of each child and, as typical of toddlers, their mood and interests varied between sessions. While there are trends, the results are still variable between children, likely representing important inter-participant differences in how they learn and engage with powered mobility.

We successfully quantified toddler exploration in both seated and standing postures while using the Explorer Mini by investigating how they learn to activate the joystick and navigate through space in multiple play sessions. This study demonstrated important differences in toddlers' initial experience and use of power mobility in seated and standing postures, especially in relation to joystick activations and distance travelled. Additionally, we have demonstrated the feasibility of collecting these quantitative metrics during powered mobility learning which has implications for all powered mobility learning, and not just restricted to this age group. Quantifying how children learn engage with their environment with powered mobility devices will help inform the future design and control of these devices to support play and development.

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