Clinical Ophthalmology

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ORIGINAL RESEARCH

The Role of a Pediatric Belt Cane in Children with Cerebral Visual Impairment

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Objective: Because children with cerebral/cortical visual impairment (CVI) may have difficulty using visual preview to guide safe navigation, including hazard detection, obstacle negotiation, and foot placement resulting in more cautious gait patterns, we evaluated whether wearing a Pediatric Belt Cane is associated with improved gait speed in children with CVI, with step length and a foot-mobility metric analyzed as exploratory outcomes.

Methods: In this pre-post observational pilot, we analyzed smartphone videos from 11 children with clinicial diagnosed CVI at baseline and 8-week follow-up while wearing a Pediatric Belt Cane. Representative walking segments were processed using MediaPipe Pose to track bilateral feet and derive gait speed, step length, and foot-mobility. Outcomes were averaged across left/right per child and compared between baseline and follow-up using paired tests.

Results: At follow-up, gait speed was higher than at baseline; step length and foot-mobility showed similar improvements. Child-level mean changes were: gait speed +66.0% ($p<0.001$), step length +49.8% ($p<0.001$), and foot-mobility +55.8% ($p<0.001$).

Conclusion: In this pilot pre-post cohort, pediatric belt cane use was associated with improved gait speed, with supportive improvements in step length and foot-mobility. Larger controlled studies are needed to confirm generalizability and clinical impact.

Keywords: orientation and mobility, developmental motor outcomes, blindness, low vision, mobility rehabilitation, assistive technology

Introduction

Cerebral/cortical visual impairment (CVI) is a leading cause of pediatric low vision in developed countries and is estimated to account for approximately 27% of visual impairment in children, frequently disrupting visually guided mobility.[1,2] Authoritative pediatric guidance emphasizes a functional, team-based approach to assessment and intervention for CVI, highlighting the downstream impact on motor development and independence.[3,4] When visual information is unreliable, children may adopt cautious gait strategies, slower speed, shorter steps, and increased reliance on somatosensory cues to maintain balance and avoid collisions.[5] From early ambulation onward, independent walking depends not only on strength and coordination but also on maintaining upright stance using sensory feedback. Children with significant visual impairment often compensate by relying more heavily on haptic/tactile input (eg, contact cues from nearby surfaces or assistive devices) to support static balance and navigation.[6,7] The Safe Toddles Pediatric Belt Cane was developed to provide forward environmental information through tactile feedback while keeping the child's hands free, an important consideration for toddlers and young children who frequently carry toys or objects and may therefore lack consistent contact-based feedback about nearby walls, obstacles, and the path ahead.[8,9] By providing a consistent tactile signal about upcoming surface changes, obstacles, and boundaries, a belt cane may reduce uncertainty during navigation and support more confident, efficient gait.

Young children (especially under ~5-6 years) may be unable to sustain the coordinated, syncopated long-cane arc typically expected of older users.[10,11] For these learners, continuous tactile path preview delivered without hand use is appealing. The Pediatric Belt Cane provides a hands-free, belt-mounted frame that supplies two-point contact and a two-step

https://doi.org/10.2147/OPTH.S572112
Received: 6 November 2025
Accepted: 15 January 2026
Published: 24 January 2026

preview of the walking path (an "autonomous arc"), enabling obstacle detection in real time while the child's hands remain free. Prior feasibility work in toddlers and preschoolers suggests the belt cane is usable in real-world routines.[8,12,13]

Observational studies indicate that compared with sighted peers, individuals who are blind or have low vision walk more slowly, take shorter steps, show cadence alterations, and exhibit reduced dynamic stability.[5,14–19] Consistent with prior literature, we focused on gait speed, step length, and a foot-mobility measure.

Prior pediatric belt cane studies have primarily focused on device development and feasibility/usability in toddlers/preschoolers with severe visual impairment or blindness, and on broad functional mobility outcomes during real-world use.[8,12] In contrast, the present study focuses specifically on children with clinician-diagnosed CVI and quantifies within-child changes in gait using a reproducible markerless video approach. We selected gait speed as the primary outcome because it is a widely used indicator of functional walking ability in pediatric rehabilitation, and changes in gait speed and step/stride length can reflect shifts toward more efficient, less cautious ambulation.[14,20–23] By extracting gait speed (primary), step length, and a foot-mobility metric from routine smartphone videos using pose-estimation, we provide child-level quantitative evidence intended to complement prior feasibility and developmental mobility reports and to support hypothesis generation for controlled trials.

Methods

Study Design and Reporting

Portions of this dataset and analytic approach were presented previously in abbreviated form as a conference abstract. The current manuscript provides the full study report with expanded cohort characterization, prespecified primary endpoint framing, and complete analytic detail.[12]

This study is a pre-post observational pilot. Reporting follows the STROBE recommendations for observational studies.[24] Consistent with common pilot-study practice, we designated a single primary endpoint (gait speed) and framed the work as feasibility/preliminary effectiveness. We summarize changes with mean differences and 95% confidence intervals.[25]

Participants

We analyzed smartphone videos from 11 children with clinician-diagnosed CVI (mean age 39.7 months, SD 17.43; all ≥21 months). Participants were included based on functional mobility vision limitations: nine had visual impairment severe enough that they could not reliably use vision during independent ambulation to avoid obstacles or drop-offs, and two were blind with no light perception. Most children received concurrent therapies (72.7% physical therapy), 54.5% had previously used a mobility device, and 91% demonstrated significant delay in independent walking. Developmental comorbidity was common (developmental delay in 6 children; intellectual disability in 4).

Intervention

The Safe Toddles Pediatric Belt Cane was fitted per manufacturer specifications. Families received an orientation and age-appropriate acclimation. The frame provides two points of contact and approximately two-step path preview while keeping the child's hands free.

Video Acquisition and Calibration

Participation consisted of caregivers submitting short walking videos recorded in routine settings; no additional in-person testing was required. The research team developed the recording protocol and provided standardized recording guidance. Videos were obtained at baseline and again at 8 weeks during straight-path ambulation on typical surfaces. Caregivers were asked to keep the child centered in the frame and to minimize other people in view. Caregivers' role was limited to video recording and submission; all subsequent processing and analyses were performed by the research team.

Pose Tracking (MediaPipe Pose)

Our objective was to quantify observed gait changes using a reproducible, markerless video-analysis method. The research team curated and segmented submitted videos to isolate representative walking clips at baseline and follow-up

and then used MediaPipe Pose to track bilateral foot keypoints.[26] These tracked keypoints were used to derive all gait metrics, and the research team performed all statistical analyses.

Outcome Definitions

Speed was calculated as the slope from linear regression of the cumulative frame-to-frame foot displacement versus time. Mobility was defined as the frame-to-frame change in foot position (X, Y, Z coordinates); we computed the cumulative displacement over each segmented clip. Step length was derived by smoothing the displacement trace with a Savitzky-Golay filter and then identifying step boundaries from inflection/zero-crossing events in the derivative; step length was the displacement between successive boundaries.[27]

Statistical Analysis

Primary analyses were at the child level using a paired *t*-test (with a Wilcoxon signed-rank check as sensitivity). We report mean change (Δ) with 95% confidence intervals and p-values. Gait speed was the primary endpoint; step length and foot-mobility were exploratory.

Ethics

The protocol was approved by the Institutional Review Board at Northern Illinois University (Protocol HS22-0077, "Pediatric Belt Cane Research"). Parents or legal guardians provided written informed consent for participation and video recording; child assent was obtained when feasible per IRB policy. This study was conducted in accordance with the principles of the Declaration of Helsinki.

Results

In child-level analyses (N=11), wearing the Pediatric Belt Cane was associated with increases across all three gait metrics. Gait speed increased by +66.0% ($p<0.001$; Figure 1), foot-mobility by +55.8% ($p<0.001$; Figure 2), and step length by +49.8% ($p<0.001$; Figure 3). Corresponding absolute mean changes with 95% CIs are reported in Table 1.

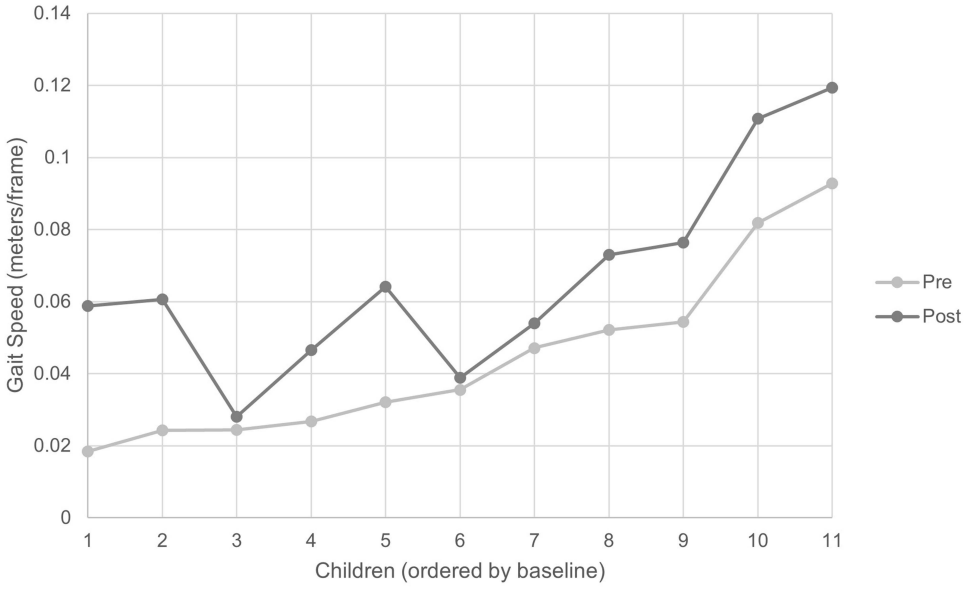

Figure 1 Gait speed.
Notes: Pre (baseline), Post (8-week follow-up with belt-mounted cane).

https://doi.org/10.2147/OPTH.S572112

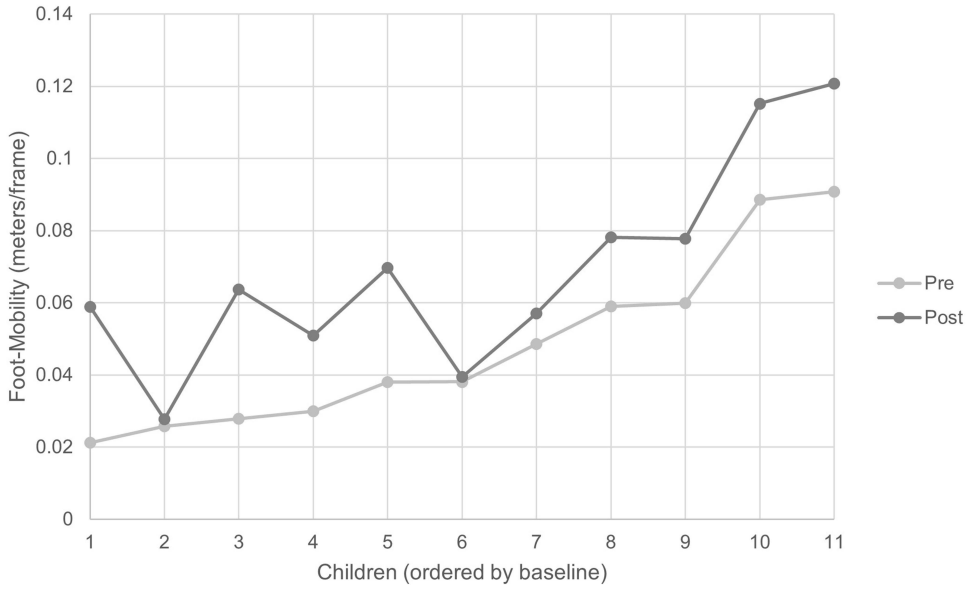

Figure 2 Foot-mobility.

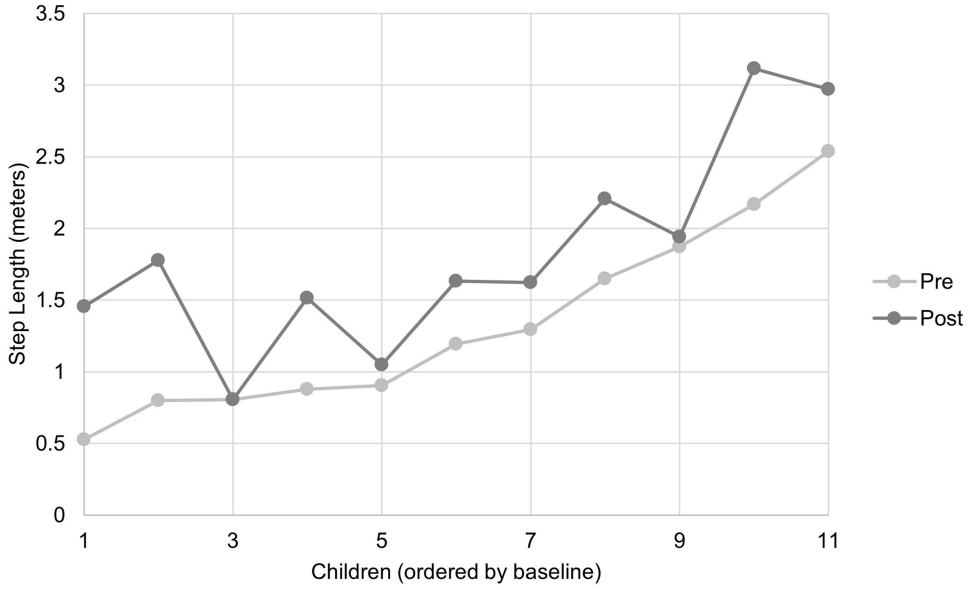

Figure 3 Step length.

Discussion

Children with CVI often cannot rely on visual preview to guide safe ambulation because CVI commonly reflects higher-order visual processing deficits rather than isolated acuity loss. Difficulties in visuospatial attention, motion processing, and dorsal-stream "vision-for-action" functions can limit hazard detection, perception of spatial layout, and real-time updating of movement plans during walking.[28–30] Visual preview is therefore important for safe ambulation because walking in everyday environments requires visually guided control of foot placement when approaching obstacles and targets.[7,31] A pediatric belt cane may help address this gap by providing hands-free, forward tactile information about the path ahead through two-point contact, offering a short "preview" of upcoming surfaces and objects while allowing children to keep their hands available for play and daily tasks.[8,32] This added tactile input may reduce cautious or "defensive" walking behaviors, such as slowing, taking shorter steps, and

Table 1 Child-Level Outcomes at Baseline and Follow-Up (N=11)

Metric (Units)	Mean (Pre)	Mean (Post)	Mean Δ, 95% CI	Mean % Change	p (Paired *t*-test)
Gait speed (meters/frame)	0.045	0.066	0.022 (0.013–0.031)	+66.0%	<0.001
Mobility (meters/frame)	0.048	0.069	0.021 (0.013–0.030)	+55.8%	<0.001
Step length (meters)	1.33	1.827	0.497 (0.261–0.733)	+49.8%	0.001

Notes: Δ = post − pre.

increasing time spent on both legs (double support), and thereby encourage more typical spatiotemporal gait parameters, including gait speed, step/stride length, cadence, and step width.[14,20,21,23] Improvements in gait speed and step length are clinically meaningful because gait speed is a widely used indicator of walking ability and functional mobility in pediatric rehabilitation and is commonly targeted in gait-focused interventions.[20–22] Because gait speed and step/stride length reflect the "pace" domain of gait, increases in these measures may indicate more efficient, less cautious walking patterns.[14,23]

In this pre-post pilot study, wearing the Pediatric Belt Cane was associated with increased gait speed, with supportive improvements in step length and a foot-mobility measure. We quantified these changes using a markerless video-analysis approach (MediaPipe) that can be applied to routine clinic or home videos, enabling repeatable gait measurement without laboratory-based markers.

Future work should evaluate age- and phenotype-specific effects, quantify dose/training exposure, compare against usual care or alternative mobility supports, and incorporate real-world outcomes (falls/near-falls, participation, caregiver-reported mobility) across varied environments and longer follow-up.

Relation to Prior Work

These findings extend earlier feasibility reports of wearable or belt canes in young children who are blind or have low vision.[8,13] Those reports described gains in independent mobility, posture, and walking fluency during regular use. Our results also align with broader literature showing slower gait and shorter steps in visually impaired populations than in sighted peers, which supports the rationale for early tactile anticipatory support.[5,14–17,19,33] This study advances the field by providing quantitative, child-level evidence in children with CVI, using a reproducible markerless video-analysis method applied in routine settings. The large, consistent gains in speed and step length support the clinical promise of early tactile anticipatory support via a belt-mounted cane.

Limitations

This study has several limitations. The sample was small and included children with a wide range of CVI presentations, and the single-arm pre-post design (no control group) means we cannot prove that the belt cane caused the observed changes. We also did not have complete clinical background information for every child (eg, CVI subtype/etiology, age at diagnosis, or prior orientation-and-mobility training and device use), which limited our ability to compare outcomes across CVI subgroups. Finally, video choice and segmentation could introduce bias, blinding was limited, and our gait measures were based on pose-estimation keypoints, which can be affected by camera angle, partial occlusion, and tracking error.

Conclusion

Wearing the Pediatric Belt Cane was associated with increased gait speed, with supportive improvements in step length and a foot-mobility measure in this pre-post pilot of children with CVI. These findings matter because gait speed is a standard indicator of functional walking ability in pediatric rehabilitation and increases in speed and step/stride length typically reflect more efficient, less cautious ambulation. Hands-free tactile path preview may therefore be a practical mobility support for children with CVI, and markerless video analysis may enable repeatable measurement in routine settings. Controlled studies with standardized CVI phenotyping and clinically anchored outcomes are needed.

Acknowledgments

We thank Dr. William Penrod (Department of Special and Early Education, Northern Illinois University) for early contributions to study planning and coordination of the NIU IRB submission. We are also grateful to our colleagues, clinical staff, and participating patients and families for their support.

Funding

All phases of this study were supported by a grant from The Lavelle Fund for the Blind.

Disclosure

Dr Grace Ambrose-Zaken is inventor, founder, president, CEO, and research director for the nonprofit Safe Toddles, the sole provider of Pediatric Belt Canes. In addition, Dr Grace Ambrose-Zaken has a patent US10,092,476 B2 issued to RF CUNY. The other authors have no conflicts of interest to disclose for this work.

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