**Symposium Title**: Beyond Motor Milestones: Rethinking Mobility Interventions and Developmental Outcomes for Infants with Down Syndrome

**Chair**: Ashley N. Collimore[[1]](#footnote-2) and Jana M. Iverson1

**Discussant**: N/A

**Overview**: Independent mobility is a key driver of infant exploration, communication, and caregiver interactions, which all support overall development. However, infants with Down syndrome (DS) typically have significant delays in motor development which may have cascading effects on other domains, such as cognition and language. Early mobility interventions may enable earlier acquisition of motor skills and support development across domains, but additional groundwork is needed before advancing to clinical trials. Specifically, there is a need to identify outcome measures that capture meaningful developmental changes in infants and toddlers with DS, beyond what standardized assessments offer, and to conduct preliminary evaluations of mobility interventions. This symposium highlights research that addresses these critical issues. The first two presentations highlight the need for targeted interventions to influence these developmental pathways and the potential utility of measures from naturalistic play and language as alternative outcome indicators that capture developmental and intervention-related changes in children with DS. Paper 1 presents data that reveal differences in locomotion, object play, and communication development in infants with DS compared to typically developing infants. Paper 2 describes a comprehensive assessment of communication profiles of toddlers with DS that combines Natural Language Sampling with standardized assessments to provide a more holistic overview of communication delays in this age group. Papers 3 and 4 present findings from pilot studies on novel, infant-driven mobility interventions for infants with DS. Together, these studies emphasize the importance of tailored interventions and assessments to foster motor, communication, and cognitive development in children with DS**.**

**Paper 1 of 4**

**Paper Title**: Trial Ready: Identifying Alternative Clinical Trial Outcome Measures for Infants with Down syndrome

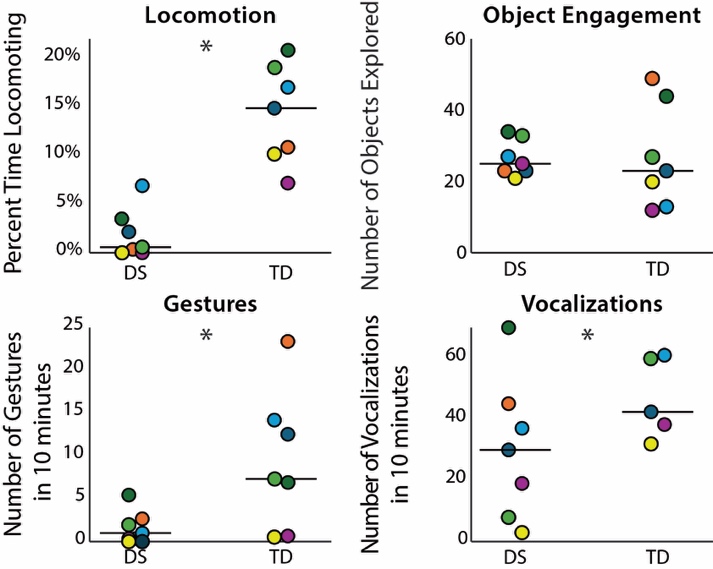
**Authors**: Ashley Collimore1, Marie Canty[[2]](#footnote-3), Anna Donato1, Erica Friedman1, Audrey Lorence1, Marc Maffei1, Katherine Pawlowski2, Sydney Reynders2, Nicole Baumer2, [[3]](#footnote-4), and Jana M. Iverson1

**Introduction**: Infants with Down syndrome (DS) experience significant motor delays[1], which limit developmental opportunities that are afforded by independent mobility and may exacerbate co-occurring delays in language and cognition[2,3]. As novel interventions aimed at promoting independent mobility become available, there is a need to evaluate their impact across multiple developmental domains. However, standardized language, cognition, and social interaction assessments often scale scores based on typically developing (TD) infants[4,5]. As a result, these assessments tend to have floor effects and fail to capture variability across infants and small but meaningful developmental changes within infants with DS. This study aimed to identify alternative outcome measures of infant development that(a) capture developmental differences between infants with DS and TD infants while reflecting variability across individuals, and (b) are sensitive to developmental changes over time in infants with DS. We focused on observational measures because they are commonly used in infant development research[6–8] but have not yet been explored in infants with DS as potential outcome measures.

**Method**: Seven infants with DS who were able to sit independently but were not yet walking were followed for six months. Infant-caregiver play sessions were video recorded at home for 30 minutes at study entry (Month 1), midpoint (Month 3), and exit (Month 6). Behavioral coding of infant locomotion, gestures to a caregiver, vocalizations, and object engagements was completed. Seven age- and sex-matched TD infants were also followed, with the same behaviors coded at identical time points. Wilcoxon signed-rank tests were used to compare observational measures between groups at each time point and to assess changes in infants with DS over time. Non-parametric tests were used due to the small sample size and an alpha level of 0.05 was used for all tests. Medians ± IQR are presented.

**Results**: All data have been collected; behavioral coding for Month 1 sessions is complete, and coding for Months 3 and 6 is ongoing (two infants completed to date). Infants with DS were primarily male (n = 4), with a mean age of 14 ± 4 mo. at the 1st visit. Only one of the infants with DS was walking by Month 6, while 5 of the 7 TD infants were walking at the first visit, and all were walking by the final visit. At the first visit, infants with DS spent significantly less time in motion (DS: 0.58 ± 2.34 %; TD: 14.85 ± 7.54%; p = 0.018), used fewer gestures (DS: 1.0 ± 2.31; TD: 7.31 ± 9.56; p=0.018), and vocalized less (DS: 30.0 ± 27.50; TD: 42.32 ± 21.60; p = 0.043), compared to TD infants (Figure 1). No significant differences were found in object play (number of unique objects: p = 0.753; time spent playing with objects: p = 0.612). Variability in infants with DS was observed across all four observational measures, with only two infants (pink and yellow circles) having 0% time in motion and one infant (yellow circle) not producing any gestures.

**Figure 1.** There are significant differences in movement, gestures, and vocalizations between infants with DS and TD infants. Colors represent age- and sex-matched pairs\* p < 0.05.



**Discussion**: Preliminary results suggest that observational measures of locomotion, gestures, and vocalizations effectively capture developmental differences in infants with DS compared to TD infants. Notably, infants with DS spent significantly less time in motion, highlighting the need for mobility-based interventions. There were no differences observed in object play between the groups; future analyses should explore whether infants with DS differ from TD infants in how they initiate object engagement. Importantly, all four observational measures showed variability across infants, a key consideration when selecting outcome measures[9]. Ongoing analyses will evaluate these observational measures’ sensitivity to developmental change. These findings are an important step in evaluating the developmental impact of mobility interventions for infants with DS.

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**Paper 2 of 4**

**Paper Title**: Characterization of Communication Profiles of Toddlers with Down Syndrome and Autism

**Authors**: Anna Stewart2,[[4]](#footnote-5) , Tanisha Chanda[[5]](#footnote-6), Alexis Monk4, Maggie Norberg2, Katherine Pawlowski2, Nicole Baumer3, Carol Wilkinson2

**Introduction:** Children with neurodevelopmental disorders (NDDs) exhibit diverse developmental trajectories, particularly in communication. For example, children with Down syndrome (DS) often experience substantial challenges with both receptive and expressive language. Expressive language impairment in DS can vary from verbally fluent to minimally/nonverbal. These delays are associated with factors like oral-motor difficulties, gross and fine motor delays, intellectual disability, and hearing loss, all common in the DS population, which add to the complexity of their language impairments[10]. Additionally, an estimated 15–30% of children with DS also meet criteria for autism spectrum disorder (ASD)[11], introducing further diversity in their communication needs. Understanding language characteristics in DS is essential to advancing knowledge and intervention strategies. However, standardized assessments often fall short in capturing the abilities of children with limited expressive language, limiting our ability to effectively track progress. Natural Language Sampling (NLS) offers a naturalistic approach, capturing expressive language features that standardized tests may overlook[12], yet no standard transcription protocol exists for children with limited expressive abilities. Further characterization of communication through NLS for toddlers with DS would both improve our understanding of early language development and provide richer tools to monitor progress related to clinical interventions**.**By combining standardized assessments (Preschool Language Scale-5 and Mullen Scales of Early Learning) with NLS, this study aims to characterize the communication profiles of toddlers with DS (n = 13) and, secondarily, to compare these profiles with those of autistic toddlers with language impairment (ASD-LI) (n = 18).

**Methods:** This pilot study analyzed natural language samples from toddlers with Down Syndrome (DS; n=13, mean age 43 months) and ASD with language impairment (ASD-LI; n=18, mean age 49 months) from an ongoing longitudinal study. Participants were primarily exposed to English, and ASD-LI participants had a PLS-5 Total Language score below 80. Language samples were collected using the Eliciting Language Samples for Analysis (ELSA-T) [13] protocol, designed to elicit expressive communication. The PLS-5 was administered to assess expressive and receptive language abilities. The Mullen Scales of Early Learning (MSEL) was administered to capture fine motor abilities. To capture variability in language use in DS and ASD-LI, level one transcription, using basic Systematic Analysis of Language Transcripts (SALT) notation, was completed. All transcriptions were done in quiet rooms.

**Results:** As expected, preschoolers with DS performed below their age expectations on the PLS for both expressive and receptive language assessments and had limited intelligibility (Table 1). Despite being younger in age, preschoolers with DS scored higher than the ASD-LI group on NLS measures and on expressive (p = 0.001) and receptive (p = 0.002) standardized assessments (Table 1, Fig.1). The DS group also demonstrated greater intelligibility (p = 0.042) and longer utterances (p = 0.019). Additionally, NLS measures, including Mean Length of Utterance in Words (MLU) and Percent Intelligibility, were strongly correlated with standard language assessments (Spearman R range 0.73-0.83). Notably, performance variability was observed across and within groups (Fig.1).

**Discussion**: Toddlers with DS and with ASD-LI had challenges in both expressive and receptive language, with both groups producing very short utterances and harder-to-understand speech. While intelligibility differed, there was no difference in total utterances per minute or responses to questions, suggesting many vocalizations were missed by standard NLS transcription. Notably, the majority of vocalizations were not intelligible and thus not included in common NLS measures (like MLU). However, these vocalizations are likely important for communication and underscore the need for NLS protocols that better characterize pre-speech and non-speech sounds. Future protocols will categorize unintelligible utterances into pre-speech, non-speech, and phoneme-level vocalizations. Such in-depth characterization may provide better measure of communication gains in response to intervention.

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**Paper 3 of 4**

**Paper Title**: Treadmill and overground stepping in infants with Down syndrome: Developmental trends and caregiver perspectives

**Authors**: Christina Hospodar[[6]](#footnote-7), Flor Enriques6, Heather A. Feldner[[7]](#footnote-8), Julia Looper[[8]](#footnote-9), Cameron Brown[[9]](#footnote-10), Kari Kretch6

**Introduction**: Independent walking is a salient developmental milestone that expands access to the physical and social environment. Children with Down syndrome (DS), a genetic condition associated with intellectual disability and neuromotor impairments, do not typically walk independently until 2+ years of age. Delays in walking onset restrict home and community participation and may adversely affect global development, so accelerating walking onset is considered an important goal for early intervention. Early stepping practice on a treadmill can promote earlier walking in infants with DS[14], but treadmill training lacks the variability, sensory input, and functionality of real-world walking. Overground mobility devices (e.g., walkers, gait trainers) may offer a promising alternative more akin to real-world walking, but little is known about the emergence of supported overground stepping in infants with DS. Here, we aimed to characterize the development of treadmill and supported overground stepping abilities in infants with DS and to explore parent perspectives regarding treadmill and overground experiences.

**Method**: Pre-walking infants with DS (*N*=15) participated at 10, 13, 16, and/or 19 months of age; *N*=8 infants participated in multiple visits for a total of *N*=24 visits (data collection is ongoing). At each visit, we measured infants’ stepping in two tasks: (1) *Treadmill*: Infants were held in a standing position over a treadmill belt moving at 0.2 m/s; and (2) *Overground*: Infants were pushed in a suspension walker (wheeled walker with an overhead harness; Figure 1) at 0.2 m/s down a hallway. We also tested whether infants could propel the walker independently. Infants’ steps were coded from video to calculate *total step rate* and *alternating step rate* (per minute). Infants’ motor skills were assessed using the Gross Motor Function Measure-88 (GMFM) to obtain summary measures of sitting, standing, and walking function and infants’ ability to perform specific motor skills: sitting, standing with hands held, pulling to stand, cruising, and walking with hands held. Caregivers completed a custom questionnaire at each visit to assess their perspectives about the two devices. General linear mixed models examined effects of task (treadmill vs. overground), age (coded as visits 1-5), and motor skills on total and alternating step rate, and caregiver questionnaire data were explored descriptively.

**Results**: Both total (*B*=10.43, *SE*=2.60, *p*<.001) and alternating (*B*=9.73, *SE*=2.38, *p*<.001) step rate increased with age, and were higher in the overground task (total: *B*=18.81, *SE*=3.53, *p*<.001; alternating: *B*=14.43, *SE*=2.97, *p*<.001). Significant age\*task interactions (total: *B*=17.23, *SE*=3.32, *p*<.001; alternating: *B*=16.06, *SE*=2.79, *p*<.001) confirmed that stepping was similar between tasks at the younger ages, but diverged by 16 months; the main effect of age was driven by increasing stepping in the overground task (Figure 2). Both total and alternating step rate were associated with GMFM Sitting score (total: *B*=1.20, *SE*=0.24, *p*<.001; alternating: *B*=0.80, *SE*=0.26, *p*=.004), and ability to pull to stand (total: *B*=15.35, *SE*=6.29, *p*=.02; alternating: *B*=18.03, *SE*=5.79, *p*=.003). Total step rate was also associated with ability to sit independently (*B*=26.40, *SE*=8.96, *p*=.005), and alternating step rate was associated with GMFM walking score (*B*=1.57, *SE*=0.60, *p*=.012) and the ability to cruise (*B*=10.62, *SE*=5.04, *p*=.04). Infants did not demonstrate independent propulsion at 10 or 13 months, but at both 16 and 19 months, 66% of infants were able to independently propel the walker.

Caregivers reported variable infant enjoyment across devices: Across 12 caregivers and 14 visits, about half of caregivers agreed or strongly agreed that their infant enjoyed using the treadmill (57%) and walker (57%). Caregivers had positive experiences with the walker, with 79% agreeing or strongly agreeing that they enjoyed using the walker with their child. Despite mixed opinions on whether it was easy for their child to use the devices (50% thought it was somewhat or very easy for their child to use the treadmill, and 57% thought it was somewhat or very easy for their child to use the walker), caregivers showed strong interest in obtaining a device for home use, with 71% agreeing or strongly agreeing that they would be interested in using the treadmill in their home, and 86% agreeing or strongly agreeing that they would be interested in using the walker in their home or community.

**Discussion**: Readiness for overground stepping emerges as early as readiness for treadmill stepping, and a suspension walker moving overground promotes more stepping activity than a treadmill at 16 months of age and beyond. Supported overground stepping demonstrates potential as a feasible method for promoting stepping practice and functional mobility in infants with DS.

**Figure 2**



**Figure 1**

A child in a walker

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**Paper 4 of 4**

**Paper Title:** Harnessing Play to Support Development: Impacts of Partial Body Weight Support for Pre-Ambulatory Children with Down Syndrome

**Authors**: Heather A. Feldner7, Alyssa Fiss[[10]](#footnote-11), Reham Abuatiq7, Mia Hoffman7, Julia Looper8

**Introduction**: Down Syndrome (DS) is the most prevalent chromosomal disorder diagnosed in the United States. Children with Down syndrome (DS) experience delayed mobility, which decreases their opportunity for exploration and impacts the development of their cognitive, communication, and social-emotional skills. Because the first years of life are critical for addressing impairments associated with DS and enabling successful participation throughout the lifespan, investigating novel interventions to facilitate supported, exploratory play and mobility during this stage is imperative. However, because children with DS are expected to walk, there has been limited exploration to date of interventions that involve temporary use of assistive mobility technologies. Both enriched play environments and partial-body weight support training have shown promise for facilitating these developmental experiences in young children with DS, however, these interventions have not yet been widely explored in combination. This study explored the impact of a Partial Body Weight Support (PBWS) harness system within an enriched play environment on gross motor development, movement counts, and mastery motivation of pre-ambulatory young children with DS.

A person in a room with a baby

Description automatically generated**Method**: We conducted a multi-site, randomized, crossover clinical trial with pre-ambulatory children with DS and their families. We used a 9’ x 9’ portable harness system (PUMA, Enliten, LLC, Fig. 1) that provided partial body weight support for children to freely explore an enriched play space in multiple positions, including floor play/crawling, pulling to stand, and cruising. In this 9-week study, children participated in play and mobility sessions 3x/week for 6 weeks: 3 weeks with the harness and 3 weeks without. Harness condition order was randomized. Assessments were completed during weeks 1, 6, and 9 using the GMFM-88, the Dimensions of Mastery Questionnaire, and activity counts using wrist, ankle, and trunk-worn accelerometers were captured at each play session.

Figure 1. The experimental setup with the PUMA Harness (Enliten, LLC), weight offset pulley system, and enriched play environment. The no friction harness support structure allowed full range of exploratory play within the 9’ x 9’ space for floor or upright play.

**Results**: Statistically and clinically significant improvements were evident in mean mid and post-study GMFM-88 scores compared to baseline values, with higher rates of change in scores during the in-harness condition compared to rates of change in the no-harness condition. No significant differences were found in parent reported mastery motivation scores. Overall activity count increases were observed, however, this was not dependent on harness condition. For participants who progressed to supported standing play, there was an inverse relationship with time spent upright (kneeling or standing) and movement counts.

**Discussion**: Children with DS moved more and improved their gross motor skills across the intervention period, regardless of whether the PBWS was engaged, however, it appears the harness did impact the rate of change on the GMFM-88, indicating its potential value in supporting early intervention for children with DS. Though activity levels measured via accelerometry increased overall, the direct impact of the in-harness condition remains unclear. Combining a PBWS harness system with an enriched play environment is a promising tool for early intervention to support motor development, social interaction, and exploration of the environment for pre-ambulatory children with DS. Portable PBWS harness systems may be useful in home, school, or clinic settings to encourage mobility and play and accelerate gross motor development and physical activity while allowing a child to explore their environment in multiple positions and interact with peers and family.

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