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Developmental Trajectories and Reference Percentiles for the 6-Minute Walk Test for Children With Cerebral Palsy.

Alyssa LaForme Fiss

Lynn Jeffries

Kristie Bjornson

Lisa Avery

Steven Hanna

See next page for additional authors

Authors
Alyssa LaForme Fiss, Lynn Jeffries, Kristie Bjornson, Lisa Avery, Steven Hanna, and Sarah Westcott McCoy

Abstract

Purpose: The purposes of this study were to: 1) document longitudinal developmental trajectories in 6MWT distances and 2) develop age-specific reference percentiles for children across different Gross Motor Function Classification System (GMFCS) levels. Methods: 456 children with CP ages 3 to 12 years of age, GMFCS Levels I-III participated. Children's motor function was classified on the GMFCS, and children completed the 6MWT two to five times across 2 years. Nonlinear mixed effect models and quantile regression were used to analyze the data. Results: Longitudinal developmental trajectories demonstrated 6MWT distances increase with age followed by a tapering as children approach their functional limit relative to their GMFCS level. Reference percentile graphs were created to monitor change over time. Conclusions: The 6MWT longitudinal developmental trajectories, reference percentiles and interpretation of percentile change presented in this paper should assist collaborative and proactive intervention planning relative to functional walking capacity for children with CP.

Background

Ambulatory children with cerebral palsy (CP) are at risk for reduced endurance as a result of primary and secondary impairments related to CP.[1] Altered body mechanics and decreased participation levels associated with variations in endurance have been seen as precursors to long-term maladaptive health behaviors such as low levels of daily exercise, [2] and reduced participation in play and social activities.[3] Research has reported that children with CP take fewer steps per day, spend less time walking[4] and engage in less physical activity than typically developing peers.[4,5] Similarly, amongst children with various pediatric disabilities, children with CP are described as having one of the most sedentary lifestyles.[6]

Encouraging physical activity, such as walking, for children with CP should be an important component of physical therapy intervention and may assist with increasing activity and participation abilities. In our previous work, better endurance was found to be related to higher motor abilities in young children (1.5-5 years) with cerebral palsy.[7] Similarly, decreased walking mobility is predictive of decreased participation in mobility, education, and social activities,[8] while increased daily walking activity is positively associated with parental report of physical quality of life in children with CP.[9] Time spent walking at higher step rates is associated with mobility-based participation in habits of daily life.[10] Pediatric physical therapists should, therefore, include monitoring of physical activity levels, including walking capacity in routine assessments of children with CP.

The 6-minute walk test (6MWT) is an easily administered, self-paced, submaximal walking test used as a measure of functional exercise capacity. Administration of the 6MWT is completed under controlled conditions in which the distance walked in 6-minutes is measured. In healthy children, the 6MWT has received support as a reliable and valid functional test for assessing exercise tolerance and endurance.[11,12] For children with CP, the 6MWT is commonly used to monitor change in functional abilities and functional outcomes with surgery.[13] Research has supported the reproducibility (ICC = 0.80)[15] and reliability (ICC=0.98)[16,17] of the 6MWT for older children and adolescents with CP, Gross Motor Function Classification System (GMFCS)[14] Levels I and II.

Fitzgerald and colleagues[13] published reference values for the 6MWT distances for typically developing children and children with CP, GMFCS Levels I-III, ages 4-17 years, noting significant differences between typically developing children and children with CP and across the GMFCS levels in distance walked, supporting the validity of the measure. Reference values for typically developing children from various countries are also available.[18-20] However, variations in the 6MWT protocol and in child characteristics and country of origin have led to variations in reference values across studies. For example, Fitzgerald and colleagues[13] assessed children with CP 4-17 years of age from Ireland on a modified 70 meter straight course with turnaround points noted at a wall and standard encouragements provided every minute to the child. Maher and colleagues[16] assessed children with CP 11-17 years of age from South Australia using a 10 meter course with cones used to signify turn around points placed at each end. Thompson and colleagues[17] completed the 6MWT with Canadian children with CP 4-18 years of age measuring laps around a 20 x 45 meter rectangular corridor with verbal encouragements provided every 30 seconds. Each of these studies used cross sectional methods to produce reference values.

Currently, the development of functional walking capacity for children with CP is not clearly described. The purpose of the **On Track** study was to document longitudinal developmental trajectories in 6MWT distances, along with age-specific distributions and reference percentiles, including the amount of change that is typical over one year on the 6MWT, for children with CP across GMFCS Levels

I-III. Such knowledge has potential clinical implications for tracking walking capacity with age and suggesting levels of endurance for walking activity. This knowledge would allow determination of expected functional levels to direct intervention, and facilitate communication with families.

Methods

The full study protocol of this prospective, longitudinal multisite study, entitled 'On Track: Monitoring Development of Children with Cerebral Palsy and Gross Motor Delay' is available elsewhere.[21] On Track assessed children ages 18-months up to the 12th birthday and aimed to develop longitudinal developmental trajectories and reference percentiles for impairments, health conditions, and participation variables for children with CP. This study was reviewed and received ethics approval from Institutional Review Boards at all participating institutions, and all parents or guardians provided informed consent, and children, as appropriate and in compliance with the specific IRB, provided assent.

Participants

A subset of 456 children with CP ages 3 years up to the 12th birthday, GMFCS levels I-III from the full On Track study participated. The age range was selected to represent preschool through elementary school aged children, and children under 3 years of age were excluded from completing the 6MWT, as they would likely have difficulty following the directions for a valid 6MWT. Children were recruited from sites across Canada, including British Columbia, Saskatchewan, Manitoba, Ontario, Nova Scotia, and Newfoundland, and four sites of the United States, including areas within and surrounding Georgia, Oklahoma, Pennsylvania, and Washington states. Participating children had a diagnosis of CP by a physician or a presentation consistent with a diagnosis of CP, including demonstration of delay in gross motor development in addition to impairments in: muscle tone, righting and equilibrium reactions, anticipatory postural movements of the head, trunk, or legs during movement, and active range of motion during movements identified by a physician or therapist. Children were excluded if they had a known medical diagnosis that was not consistent with CP that could impact the results of this study (e.g. degenerative condition) or their parents were unable to speak and understand English, French or Spanish. Continued eligibility to participate was confirmed throughout the study so that the final sample represented children with CP. Therapist assessors provided information questioning the eligibility of seventy-one children either before recruitment or during study assessments. This information was reviewed a physiatrist who made recommendations regarding the eligibility of each of these children, and 11 children were excluded from the final sample based on these reviews. Attrition was tracked across all study visits and is documented in Supplementary File 1. Demographic information of the children and their families is included in Table 1.

Procedures

Children participated in up to five assessment sessions with a trained physical or occupational therapist in their home or clinic setting. Assessors were trained in research ethics, On Track study methods, and in how to complete study measures during a day-long training session with study investigators. Children in the full On Track study participated in one of two study protocols, a 2-visit study or a 5-visit study. Assessment time points for the 2-visit study included baseline and 12-months and for the 5-visit study included baseline, 6-months, 12-months, 18-months, and 24-months. Children from both study protocols were included in this study. (See Supplementary File 1). Children participated in the larger On Track study as young as 18-months of age, while the entry point for completing the 6MWT was 3-years of age. Due to this, some children did not complete the 6MWT until a later assessment session, such as their 6-month or 12-month assessment, and earlier 6MWT data was considered missing. Therefore, the number of children available to participate at each testing session varied. The therapist assessor was consistent for an individual child over time except in the rare instances where families moved or assessors were not available to complete a particular assessment.

The therapist assessors completed the GMFCS via consensus with parents.[22] The GMFCS is a five-point classification system used to describe gross motor function ability in children with cerebral palsy with distinctions between levels made based on functional abilities, use of assistive technology, and quality of movement.[14] The GMFCS was independently completed by both the assessor and the parent, and then the child's classification was discussed in attempt to reach consensus. This method of consensus classification was used because fundamentally, we believe that parent's know their children best, and parents are able to describe their usual performance across multiple settings.[22] Consensus was reached 97.8% of the time, and all disagreements were within one level.[22] Based on study protocol, the final classification used was the parent rating with specific rules applied to determine if the assessor classification should be used instead. The assessor classification was used in instances where the therapist provided compelling written documentation of the child's capability that was lower than the parent classification, the incorrect age band for the GMFCS was used, or the therapist reported that the family was not able to participate in discussions to reach consensus on GMFCS levels.

The child then completed the 6MWT following slight modifications to the American Thoracic Society (ATS) Guidelines.[23] Therapist assessors were instructed to have the child walk either indoors or outdoors on a large (about 100 feet or 30 meters), flat (no hills or bumps), hard terrain (asphalt, pavement). A standardized course was not used as the assessments occurred in both home and clinic settings. As a minor modification to the standard guidelines, assessors were instructed that the walking course was to be selected so that the child would not be required to make a 180 degree turn, which may interfere with walking cadence. The child was asked to wear comfortable footwear and clothing, including orthoses, if regularly used, and was permitted to use his/her typical assistive device, if any. If the child used multiple assistive devices, he/she was instructed to use the device that allowed for the most sustained walking cadence or what he/she would typically use for long walks.

Prior to beginning the 6MWT, the assessor marked the starting line to allow for re-measurement, if needed. The assessor then explained the directions for the 6MWT to the child using standardized instructions. The distance walked was measured using a calibrated measuring wheel, and the assessor used a stopwatch to keep track of the allocated time. Standard verbal cues were provided on a laminated card to the assessors with instructions to provide standard encouragements at each minute during the test, consistent with ATS Guidelines.[23] If the child started to talk during the walk, which subsequently slowed the walking pace, the assessor was instructed to re-direct the child to pause the conversation until after the walk was completed. Creativity was encouraged to keep the child engaged in the walking task for the full 6-minutes. Assessors recorded the total distance walked in 6-minutes, the specific location of the testing, use of orthoses or assistive devices, impact of weather and terrain, whether the test was representative of the child's typical mobility based on parent input, and any other potential protocol deviations in the data collection booklet. This descriptive information is presented in Supplementary File 2. Assessors were instructed to attempt to replicate the location of the 6MWT for all subsequent assessment sessions, as closely as possible.

Data Analysis

Data from both the 2-visit and 5-visit study protocol were merged for analysis. Across all time points, the 6MWT was missing in 118 of 1611 (7.3%) assessments for a variety of reasons such as lack of a suitable testing location, inability or unwillingness of the child to follow instructions, or lack of availability of appropriate assistive device. These data were imputed, along with all other missing outcome data for the study, using a mixed-effects random forest method via a custom R function based on the code of Hajjem and colleagues.[24] Full details of the missing data procedure for the On Track study are given elsewhere.[21]

Longitudinal developmental trajectories

To create longitudinal developmental trajectories describing the average change in the 6MWT distance with respect to age, separate nonlinear mixed-effects models[25] were fit for children in each GMFCS level. Based on inspection of the raw data, plotting individual's change over time within each GMFCS level, an asymptotic offset model was fit allowing for early change followed by a leveling off toward a limit of performance. Three possible models were considered, all with the same functional form but specifying different parameter restrictions or centering (see the statistical supplement in Appendix for details). These asymptotic models have a rate parameter, an asymptote or limit parameter and, if necessary, an offset parameter to improve model fit. Following the methods of Hanna et al.,[26] the rate parameter was re-parameterized to an Age-90 parameter, corresponding to the length of time required for 90% of the limit to be achieved. In this model, the offset parameter corresponds to the age at which the expected score is zero, and so is an estimate of the earliest age at which the child can be measured by the 6MWT test. Random effects were fit for each parameter to estimate the variability in change parameters among children. Models were fit using the nlme package in R (see statistical supplement in Appendix for details).

Reference percentiles

The 6MWT data from the first, 12-month, and 24-month visits were analyzed via quantile regression to construct cross-sectional reference percentiles for each functional classification level. To maximize the sample size, the analysis included up to three 6MWT assessments from each child, treated as cross-sectional. This is consistent with procedures used for published percentiles of gross motor function in CP.[26] The quantregGrowth package in R was used, which uses linear combinations of multiple basis functions to estimate smooth quantiles across the age continuum and constrains the percentiles to be non-crossing.[27] These reference percentiles describe the distribution of 6MWT distances at each age within each GMFCS level.

Using these reference percentiles, which determine a child's 6MWT percentile score based on their age and GMFCS level, we calculated percentile scores for all children with baseline and 12 month assessments. The amount of change in each child's percentile score over this twelve-month period was calculated by subtracting the baseline percentile score from the twelve-month percentiles score. The distribution of these 12-month change scores was used to estimate bands that encompass 50% and 80% of changes. These bands quantify the amount of change in reference percentiles that is typical in this clinical population. Following Hanna et al,[26] we recommend that children whose percentile changes are within the 80% limits can usually be described as 'developing as expected' for their age and GMFCS levels.

Results

Descriptive data for the 6MWT **are** presented in Table 1. Longitudinal developmental trajectories for the 6MWT by GMFCS level are shown in Figure 1 with the accompanying model parameters in Table 2. Overall in our sample, a model that assumes 6MWT distances increase initially with age followed by a tapering as children approach their functional limit relative to their GMFCS level fits these data well. Table 2 presents the fixed effect estimates of the functional limit, rate of increase (reparametrized as the length of time required to achieve 90% of the limit) and an offset term, age and score 0, which could be conceived as the youngest age at which the 6MWT is relevant for children in that GMFCS level. Full details of the model, and the parametrizations used are in the Appendix. The estimated population value of the functional limit at age 12 years was highest at Level I, with lower scores in Level II and III, and no overlap of the 95% Confidence Interval (CI), which suggests, that the expectations for endurance for children at age 12 are different for different GMFCS levels. The functional limits identified for 6MWT differences **were** 417.0 meters (95% CI=397.2, 437.1 meters), 342.0 meters (95% CI= 310.0, 374.0 meters), and 180.7 meters (95% CI = 158.5, 203.0 meters), for children in levels I, II, and III, respectively.

Figure 2 shows the estimated reference percentiles for each GMFCS level, plotted at the 3rd, 5th, 10th, 25th, 50th, 75th, 90th, 95th, and 97th percentiles. Additional versions of these figures and tabulated percentiles are available on the On Track study website: https://www.canchild.ca/en/research-in-practice/current-studies/on-track. Table 3 provides the mean and standard deviation of the change in percentile score over a one-year period by GMFCS level, along with the range of the central 50% and 80% of change scores. Children in GMFCS Level I changed, on average, one percentile over the year, with 80% of the sample changing between -26 and +28 centiles. This indicates that, for children in this level, decreases of up to 26 centiles, and increases of up to 28 centiles over a one-year period are in the normal range. Similar interpretations are made for children in levels II and III.

Discussion

Longitudinal developmental trajectories provide therapists and families with a resource to determine if a child's performance on the 6MWT is consistent with distances observed in other children with CP of similar age and functional ability level. In examining the longitudinal curves, children in level I achieved 90% of total change, on average over 50 months, and as expected, demonstrated the highest functional limit of all levels. Children in level II developed over the longest time, around 69 months, and did not plateau by age 12 years. We hypothesize that this may be the result of children in level II taking longer to develop strength and balance abilities than children in level I. This suggests that children with CP at GMFCS level II should be tracked into older ages to determine when, and if, a plateau would occur. Children in Level III achieved most of their change in the shortest amount of time, with 90% of change occurring, on average, over 20 months. Children in level III also demonstrated the lowest functional limit, which was expected as children in this level typically require assistive devices to ambulate, potentially impacting their functional walking capacity. Overall, this decrease in 6MWT distances across GMFCS levels is consistent with previously identified relationships between increasing GMFCS level and increased energy expenditure of walking.[28]

Across all levels, more change occurred, on average, from ages 3-5 than from ages 5-12 years. This finding is consistent with the overall patterns of gross motor development of children with CP measured on the Gross Motor Function Measure (GMFM) reported by Rosenbaum et al.[29] Children in GMFCS levels I-III were reported to reach 90% of their motor development potential on the GMFM prior to 5 years of age.[29] These findings suggest that intervention focused on functional walking capacity should begin as early as 3 years age to facilitate development and functional mobility.

There was variability in the distances children with CP walked on the 6MWT, even within GMFCS levels. Due to this variability, the longitudinal developmental trajectories can provide a description of the average development of 6MWT abilities for children with CP at a given GMFCS level, but are less clearly related to evaluating change for an individual child over time. Because of this, these developmental trajectories should be used as a prognostic guide for judging what changes in 6MWT distances may be anticipated, but should not serve as an evaluative tool to monitor change of an individual child over time. The longitudinal developmental trajectories may improve therapists and families' conversations about future expectations and assist with collaboration to inform intervention planning.

In contrast to the longitudinal developmental trajectories, the reference percentiles describe the distribution of abilities as children develop, and can be used as an evaluative tool. Therapists can use a single assessment graphed on the reference percentiles to identify a child's individual strengths and limitations related to functional walking capacity and endurance for walking activity and can identify how far above or below the 50th percentile the child is performing. Depending on the child's performance, walking capacity may be identified as an area of strength, relative to peers, or as a potential area for intervention focus. Reference percentiles also allow for the tracking of a child's change across time for comparison of how a child is developing on the 6MWT based on the child's individual trajectory and relative to peers of the same functional ability level and age. A second administration of the 6MWT assessment at a later date provides information regarding individual change in endurance for walking activity over time. The comparison of reference percentiles from the two assessments allows therapists and families to determine, specific to the percentile where the child individually starts and ends, if a child's 6MWT distances are progressing 'as expected' (change in individual percentiles no greater or less than the data found to cover the 10-90th percentile), 'more than expected' (change in individual percentile greater than that calculated for the 90th percentile), or 'less than expected' (change in individual percentile less than that calculated for 10th percentile) over time, depending on the individual child's trajectory and functional ability level.

Therapists must be aware, however, that due to the variability in children's developmental progress, large changes in reference percentiles can occur over 12 months and still be categorized as progressing 'as expected.' For example, for children at GMFCS Level II, the difference between a first and second percentile score of +28 (i.e. an improvement of more than 27 percentile points) would be considered 'more than expected', while a second percentile score of -32 (i.e. a decline of more than 31 percentile points) would be considered 'less than expected' over an interval of approximately one year. Because reference percentiles represent a relative standing at a moment in time, therapists and families should also consider the context of the testing sessions (i.e. child's cooperation with testing, environmental distractions, etc.) to assess validity of the measurement. In visual analysis of the reference percentiles for the 6MWT, it is interesting to note that the bottom 5th percentile and the top 5th percentile for children at GMFCS Level I and III diverge away from the 50th percentile as children get older, whereas this does not seem to occur within the GMFCS Level II data. **This may be noted because** 6MWT distances for children in level II do not demonstrate a plateau at this age and a similar deviation would occur at a later age. Alternatively, this could represent a statistical anomaly in the data, and this finding may need to be explored further in future research.

To demonstrate the application of these resources to practice, the case of Sophia (pseudonym), a 10 year-old girl with CP, classified as GMFCS level II is presented. In examining the longitudinal developmental trajectories for children in level II, it is noted that, on average by age ten, children have reached 90% of their functional limit in 6MWT distances, and there are only small increases in 6MWT distances to be expected with age. At her first assessment at age 10 years, 0 months, Sophia walked

251.5 meters during the 6MWT, which is below the average distance for children her age in level II. Additionally, the developmental trajectories suggest to the Sophia's therapist and family, that large improvements in 6MWT distances would not be a realistic expectation in intervention planning. In looking more closely at Sophia's individual 6MWT distances, the reference percentiles were considered. Her initial assessment 6MWT distance of 251.5 meters placed her in the 15th percentile for her age and GMFCS level, demonstrating specifically where she falls compared to others of her age and functional ability. During the second assessment at 11 years, 0 months, Sophia walked 307.5 meters, placing her in the 35th percentile. The difference in reference percentiles indicates a 20-percentile improvement between assessments, and although this seems like a large change, our data suggest that such changes are common and that she is changing 'as expected' (-31 to +27, Table 3). This information can assist in focusing collaborative discussions of Sophia's current endurance for walking activity and future intervention needs based on her and her family's goals. Although she is developing as expected, it would also be encouraging to note that her functional walking capacity has increased over the year. Discussion of what strategies the family and Sophia are currently using to encourage walking activity performance in daily life would be important to support continued positive progress in this area.

Limitations

The convenience sample used in this study presents a potential limitation; however, the GMFCS distribution of the full On Track study cohort sample is comparable to incidence data reported in the literature, supporting the applicability of the findings.[30] Two study protocols (a 2-visit and a 5-visit protocol) were merged for the analysis of this work. This led to variation in the number of children who were available to be assessed at each time point. In addition, children in this study completed the 6-MWT beginning at age 3 years, so data on children that enrolled in the larger On Track study prior to the age of 3 years are not available for all assessments. This contributed to the variation in the number of children assessed at each time point. The amount and focus of intervention was not controlled for children in this study and may contribute to the variability noted across children. Finally, variations in the location of the 6MWT, due to weather or family relocation, may have impacted the distance walked for some children.

Conclusion

The use of longitudinal developmental trajectories and reference percentiles allows for conversations about future development and detailed monitoring of walking capacity to inform collaborative intervention planning. Variability in 6MWT distances for children with CP, even within GMFCS level, exists and must be taken into consideration as therapists use these resources in practice. By monitoring walking capacity, therapists can work with children and their families to develop intervention activities that help to maintain or improve walking and/or overall physical activity levels. This, in turn, may promote increased participation in mobility, education, and social activities and improved quality of life for children with CP.

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Figure 1. Six-minute walk test longitudinal developmental trajectories by Gross Motor Function Classification System (GMFCS) level

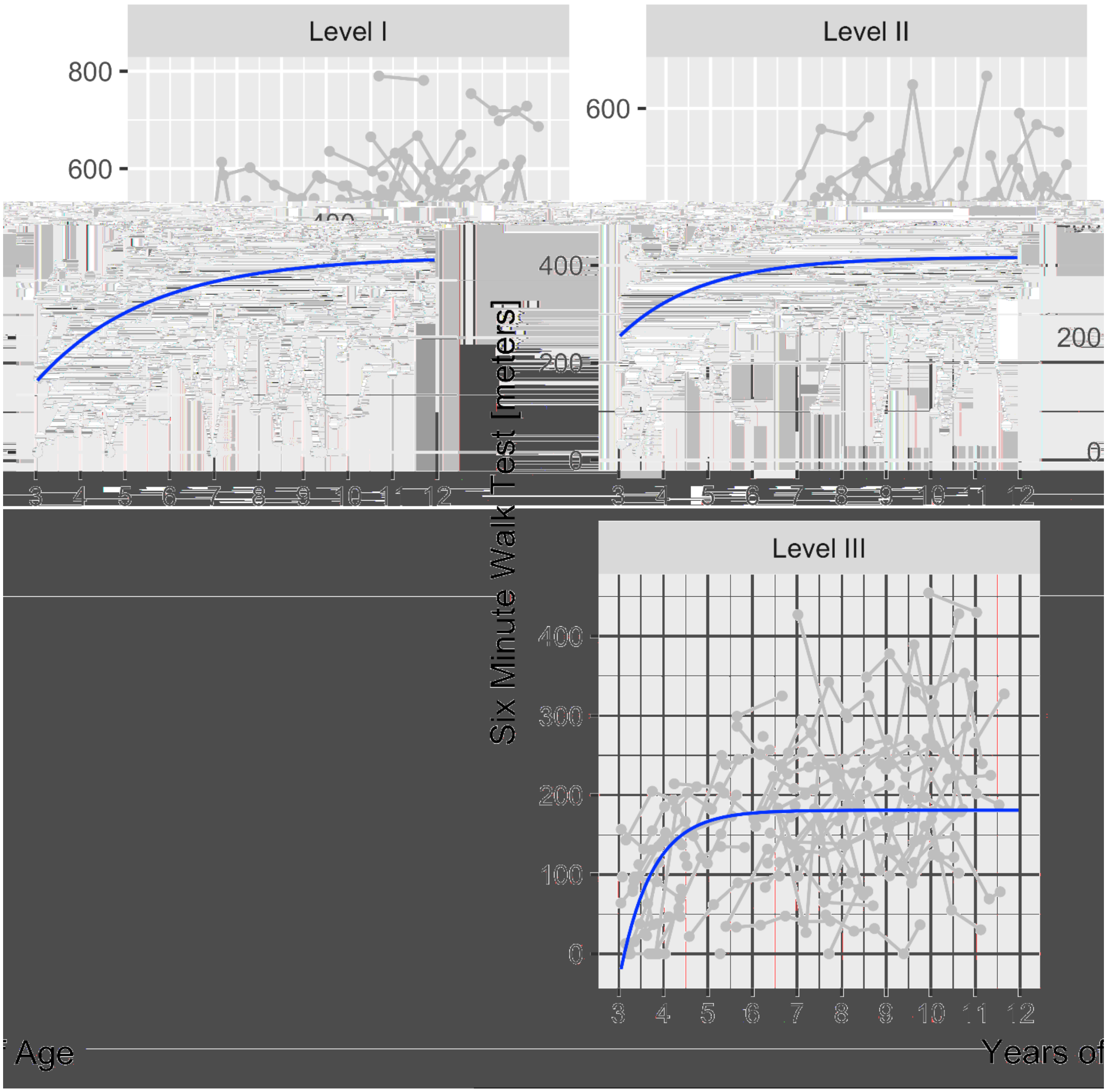

Figure 2. Six-minute walk test reference percentiles by Gross Motor Function Classification System (GMFCS) level

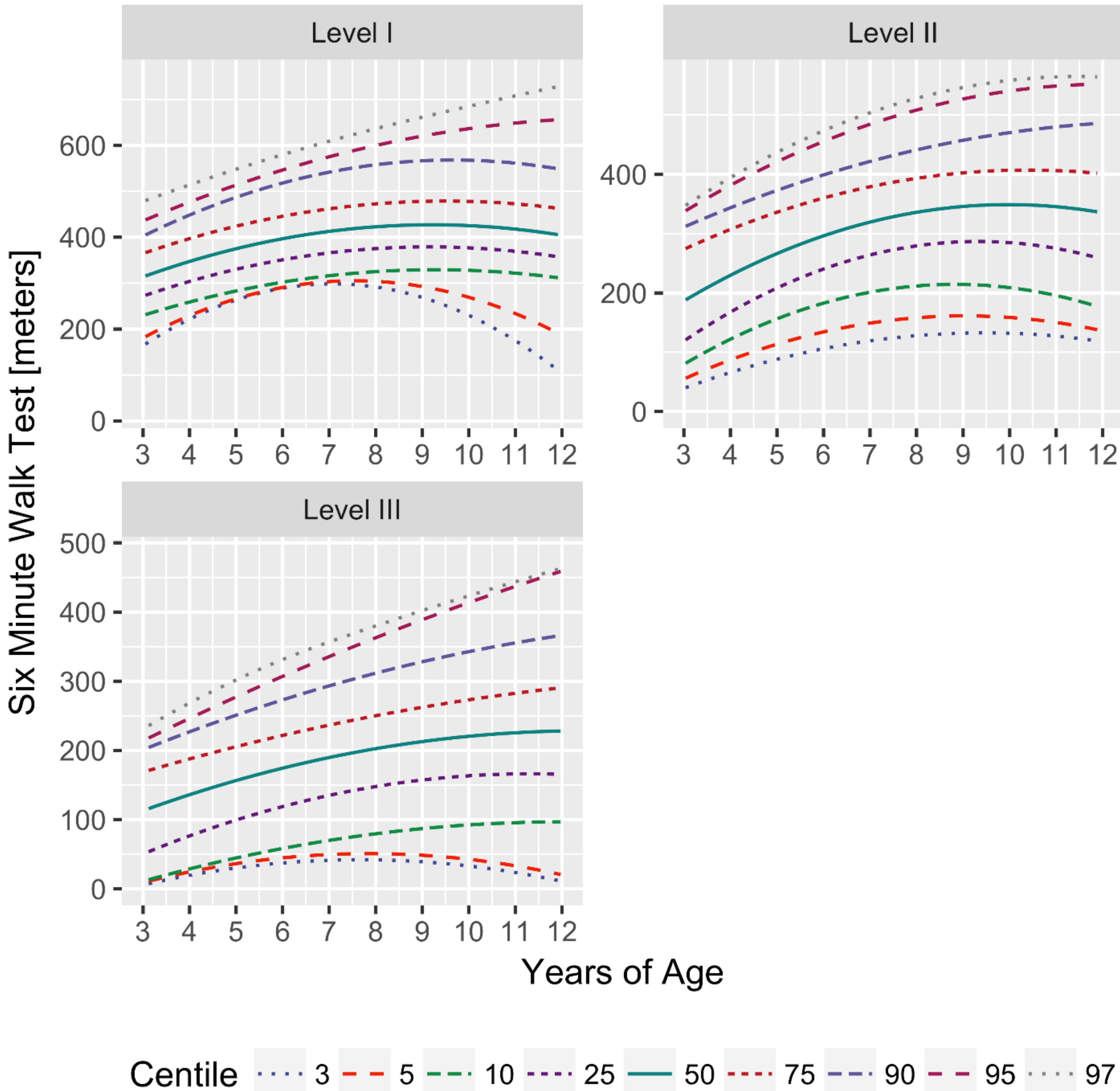

Table 1. Child and Parent Demographics

		Participants		
		Baseline Completed n=376 (%)	**12-Month Completed n=408 (%)**	**24-Month Completed N=274 (%)**
Child Age, years	Mean (SD)	6.9 (2.2)	7.3 (2.6)	7.9 (2.7)
	Minimum - Maximum	3.1 - 11.9	3.0 – 13.1	3.3 - 14.0
Child Gender	Male	209 (56)	221 (54)	150 (55)

	Female	167 (44)	187 (46)	124 (45)
Child GMFCS Level	I	176 (47)	201 (49)	135 (49)
	II	138 (37)	144 (35)	97 (36)
	III	62 (16)	63 (16)	42 (15)
Child Distribution of Involvement*	Monoplegia	4 (1)	5 (1)	6 (2)
12-Month (n = 407)	Hemiplegia	159 (42)	173 (42)	112 (41)
	Diplegia	139 (37)	145 (36)	98 (36)
	Triplegia	23 (6)	25 (6)	17 (6)
	Quadriplegia	51 (14)	59 (15)	41 (15)
Child race* Baseline (n = 368)	American Indian/Alaska Native	8 (2)	8 (2)	3 (1)
12-Month (n = 402)	Asian	23 (6)	23 (6)	13 (5)
24-Month (n = 270)	Black/African American	25 (7)	33 (8)	26 (10)
	White	276 (75)	295 (73)	200 (74)
	Multi	36 (10)	43 (11)	28 (10)
Child ethnicity*	Hispanic	26 (7)	27 (7)	22 (8)
Baseline (n = 372-373)	Non-Hispanic	346 (93)	379 (93)	251 (92)
12-Month (n = 406-407)				
24-Month (n = 273-274)	Aboriginal	16 (4)	18 (4)	7 (3)
	Non-Aboriginal	357 (96)	389 (96)	267 (97)
Parent respondent race*	American Indian/Alaska Native	9 (2)	9 (2)	3 (1)
Baseline (n = 369)	Asian	26 (7)	27 (7)	12 (4)
12-Month (n = 403) 24-Month (n = 271)	Black/African American	21 (6)	28 (7)	23 (9)
	White	302 (82)	325 (81)	224 (83)
	Multi	11 (3)	14 (3)	9 (3)
Parent respondent ethnicity*	Hispanic	16 (4)	18 (4)	13 (5)
Baseline (n = 371)	Non-Hispanic	355 (96)	387 (96)	259 (95)
12-Month (n = 405)	Aboriginal	10 (3)	11 (3)	3 (1)
24-Month (n = 272-273)	Non-Aboriginal	361 (97)	394 (97)	270 (99)
Parent respondent age, years* Baseline (n=367) 12-Month (n = 401) 24-Month (n = 269)	Mean (SD)	38.6 (7.8)	38.1 (8.0)	37.5 (7.4)
	Mother	330 (88)	360 (88)	248 (91)

Parent respondent relationship to child* Baseline (n = 373) 12-Month (n = 407)	Father	33 (9)	36 (9)	17 (6)
	Other	10 (3)	11 (3)	9 (3)
Parent respondent education* Baseline (n = 370) 12-Month (n = 404) 24-Month (n = 272)	High School or less	69 (19)	77 (19)	51 (19)
	Community College / Associate's Degree	122 (33)	132 (33)	73 (27)
	University	179 (48)	195 (48)	148 (54)
Family Income* Baseline (n = 307) 12-Month (n = 342) 24-Month (n = 231) (CAD or USD)	≥$75,000	170 (55)	190 (55)	127 (55)
	$60,000 - $74,999	40 (13)	47 (14)	30 (13)
	$45,000 - $59,999	23 (8)	26 (8)	22 (9)
	$30,000 - $44,999	24 (8)	24 (7)	18 (8)
	≤$30,000	50 (16)	55 (16)	34 (15)
Family Composition Baseline (n= 355) 12-Month (n = 388) 24-Month (n = 262)	Adults (mean, SD)	2.1 (0.6)	2.1 (0.7)	2.1 (0.6)
	Children (mean, SD)	2.3 (1.0)	2.2 (0.9)	2.3 (1.0)
Country	Canada	192 (51)	219 (54)	94 (34)
	United States	184 (49)	189 (46)	180 (66)

GMFCS= Gross Motor Function Classification System Level
CAD = Canadian Dollars
USD = United States Dollars
SD = standard deviation
* report based on the available information
Notes: 'mother' includes mother, adoptive mother, foster mother, or custodial mother; 'father' includes father, adoptive father, or step father; 'other' includes grandparent, or aunt.

Table 2. Model parameters across GMFCS levels

	Level I	**Level II**	**Level III**
Children	220	160	76
Observations	788	574	248
Mean Observations per child	3.6	3.6	3.3
Fixed Effects[1]			
Limit [meters]	417.0	342.0	180.7
(95% CI)	(397.2, 437.1)	(310.0, 374.0)	(158.5, 203.0)
Age-90 (months)	50.4	69.1	20.3
(95% CI)	(34.1, 74.6)	(44.4, 107.4)	(11.0, 37.3)

	Level I	Level II	Level III
Age at Score of 0 (months)	15.6	22.7	37.5
(95% CI)	(6.6, 24.7)	(14.5, 30.9)	(34.3, 40.7)
Random Effects[2]			
Residual SD (meters)	54.6	60.5	43.4
50% Ranges			
Limit (meters)	(361.5, 472.7)	(284.1, 399.9)	(127.1, 234.7)
Age-90 (months)	(50.4, 50.4)*	(56.4, 84.6)	(20.2, 20.3)*
Age at Score 0 (months)	(15.6, 15.6)	Not estimated	(34.4, 40.5)
Predicted Values (meters)			
Mean (95% CI)			
3 years	248.1 (219.5, 267.9)	117.7 (81.1, 143.6)	Not applicable
5 years	360.9 (348.1, 372.8)	241.7 (226.8, 256.0)	164.6 (146.0, 182.3)
12 years	415.1 (400.2, 430.1)	334.1 (313.6, 353.3)	180.7 (162.8, 199.0)
change 3 to 5 years	112.5 (90.8, 145.7)	124.1 (96.6, 162.8)	216.1 (140.5, 360.6)

1. Fixed effects describe the average shape of the curves within GMFCS level: Limit refers to the expected maximum distance, in meters a child will achieve, Age-90 indicates the average number of months required to achieve the limit and Age at Score 0 the average earliest age that testing with the measure could commence.
2. Random effects describe the sample variation in each of the fixed effects (50% ranges) and residual error

* Random effects were negligible.

Table 3. Percentile changes over one year

	Level I	Level II	Level III
N	217	147	73
mean	1	1	5
sd	23	23	20
25-75%	-11, +14	-6, +13	-2, +14
10-90%	-26, +28	-31, +27	-14, +25