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Variability explained by strength, body composition and gait impairment in activity and participation measures for children with cerebral palsy: a multicentre study

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Abstract

Objective: To determine the amount of variability in scores on activity and participation measures used to assess ambulatory individuals with cerebral palsy explained by strength, body composition, gait impairment and participant characteristics.

Design: Multicentre prospective cross-sectional study.

Setting: Seven paediatric–orthopaedic specialty hospitals.

Participants: Three hundred and seventy-seven ambulatory individuals (241 males, 136 females) with cerebral palsy, Gross Motor Function Classification System (GMFCS) levels I–III (I = 148, II = 153, III = 76), ages 8–18 years (mean 12 years 9 months, SD 2 years 8 months).

Methods: Participants completed assessments of GMFCS level, patient history, lower extremity muscle strength, Gross Motor Function Measure (GMFM-66), Pediatric Outcomes Data Collection Instrument (PODCI), instrumented gait analysis, 1 minute walk test, Timed Up-and-Go and body composition. Multiple linear regression and bootstrap analyses were performed for each outcome measure, stratified by GMFCS level.

Results: The amount of variability in outcome measures explained by participant characteristics, strength, and gait impairment ranged from 11% to 50%. Gait impairment was the most common predictor variable and frequently explained the greatest variance across all outcome measures and GMFCS levels. As gait

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impairment increased, scores on outcome measures decreased. Strength findings were inconsistent and not a primary factor. Body composition contributed minimally (<4%) in explaining variability. Participant characteristics (cerebral palsy type, gestational age and age at walking onset), were significant predictor variables in several models.

Conclusions: Variability in outcome measure scores is multifaceted and only partially explained by strength and gait impairment illustrating the challenges of attempting to explain variation within this heterogeneous population. Clinicians treating individuals with cerebral palsy should consider this when developing treatment paradigms.

Keywords

Cerebral palsy, outcome measures, strength, body composition, Gillette Gait Index, gait

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Introduction

Physical function of children with cerebral palsy varies, even within Gross Motor Function Classification System (GMFCS) level.[1] This variation in physical function is seen in the ranges of scores obtained on outcome measures frequently used to assess functional status of individuals with cerebral palsy. Previous work found that scores on outcome measures in children with cerebral palsy illustrated variability within GMFCS levels and a degree of overlap between GMFCS levels.[1] The predictor variables that contribute to the variability are not well understood but previous work has shown that strength,[2,3] body composition,[4] gait impairment[5] and type of cerebral palsy (hemiplegia or diplegia)[6] are related to physical function in this population.

The World Health Organization's International Classification of Functioning Heath and Disability framework is used to document characteristics of health and functioning in children.[7] Lower extremity muscle strength, body composition and gait impairment are within the body structure and function domain, while outcome tools including the Gross Motor Function Measure (GMFM-66), 1 minute walk test, Timed Up-and-Go, walking speed, and the Pediatric Outcomes Data Collection Instrument (PODCI) subscales are within the activity and participation domain. Participant characteristics, including age at the time of assessment, sex, cerebral palsy type (hemiplegia or diplegia), gestational age and age at walking onset are part of the contextual factors domain. Determining how strength, body composition, gait impairment and participant characteristics contribute to the variability in scores on outcome measures used to assess mobility, balance, and walking capacity will help focus interventions that improve or prevent declines in functional ability for ambulatory individuals with cerebral palsy.

Children with cerebral palsy are weaker than their age-matched peers.[8] Insufficient physical activity, decreased and imbalanced central input to muscles, altered muscle elastic properties, and spasticity can contribute to muscle weakness.[9] Lower extremity strength in this population is related to physical function, as measured by the GMFM-66, and knee extensor strength is related to walking velocity.[2,10,11] This relationship, however, has been controversial with some studies finding that strength training does not lead to improved mobility,[12,13] while another reported that function and gait improvements from progressive strength training were greater in pre-adolescents.[14]

The prevalence of obesity in youth with cerebral palsy has increased over the past decade[15] at rates comparable to the typically developing population.[16] Although obesity can contribute to poor long-term health,[17] it is unknown whether increased body fat negatively impacts physical function in individuals with cerebral palsy. Inadequate strength relative to body weight may make activities like walking, running or jumping too strenuous, causing decreased physical functioning.

Gait impairment and characteristics of a child with cerebral palsy are also related to function. Gait parameters such as cadence, normalized velocity, hip and knee excursion, and percentage of single support are correlated to function as measured by the GMFM.[5] Using a normalcy index that quantifies gait deviations from normative values, Tervo et al.[18] found the normalcy index was predictive of global physical functioning. Characteristics such as type of cerebral palsy and age of the participant are also related to function with children with hemiplegia and diplegia having distinct differences in motor functioning[6] and gait functional ability deteriorating over time.[19]

The study purpose is to determine the amount of variability in scores on measures of activity and participation that can be explained by measures of body structure and function and participant characteristics. Using percent variance, predictor variables most likely to predict better performance on outcome tools will be identified. It was hypothesized that strength would explain the most variability in the scores obtained on the studied outcome measures, and gait impairment and body composition would explain additional variability.

Methods

This study was part of a four-year prospective multicentre study with cross-sectional and longitudinal components. Participants were a convenience sample of eligible patients from seven paediatric orthopaedic hospitals. Each site obtained Institutional Review Board approval and consent and Health Insurance Portability and Accountability Act forms were completed.

Inclusion criteria were patients with a diagnosis of cerebral palsy, GMFCS levels I–III, age 8–18 years, who could complete a gait analysis. Individuals who had undergone lower extremity orthopaedic surgery within a year, had botulinum toxin injections within four months, or had an operational baclofen pump were excluded.

Study personnel were trained prior to the start of the study on administration of all test measures using a standardized testing protocol. Strength of the hip flexors, extensors, abductors, and adductors, knee flexors and extensors, and ankle plantar flexors and dorsiflexors were assessed with a hand-held dynamometer (JTECH PowerTrack II Commander, Salt Lake City, UT, USA) according to a published protocol.[20] Previous studies have shown that hand-held dynamometry for the muscle groups included in this study had high within-session reliability using this protocol with intraclass correlation coefficient (ICC) >0.79.[20,21] The maximum force from three trials for each muscle was normalized to body weight, left and right limbs averaged, and used as the strength score for that muscle. The *z*-scores were then calculated by examiner to adjust for systematic differences between assessors. The mean and standard deviation of the weight-normalized strength measure of each muscle for all participants tested by an examiner were calculated. The mean value was subtracted from the strength measure for each participant tested by that examiner and divided by the standard deviation. The resulting *z*-scores reflected a relative measure of strength by examiner; this was used in the analysis to evaluate the impact of strength on outcome tool scores.

Three aggregate strength measures were defined: total strength, total extensor strength and strength ratio. Total strength was calculated as the mean of the maximum strength values for all muscles bilaterally, and was intended to reflect overall strength. Total extensor strength is the sum of the maximum strength value of the hip and knee extensor and ankle plantar flexor strength bilaterally, and was intended to reflect strength of primary support muscles. Strength ratio was calculated by dividing total strength of the right limb by the left limb for individuals with diplegia and involved to uninvolved limbs for individuals with hemiplegia and was intended to reflect strength asymmetry between sides.

Three-dimensional gait analysis was performed using standard protocols.[22] Three trials were collected during barefoot walking with standard aids. The Gillette Gait Index,[23] an index of gait impairment in which larger values indicate greater levels of impairment, was calculated for each limb and averaged. Reference norms from a single site were used in the calculation to reduce variation.[24]

Walking speed was normalized to percentage of age-matched normals.

Using a Quadscan 4000 Bioelectrical Impedance Analysis device (Bodystat Limited, UK), body composition was measured twice bilaterally and averaged to obtain mean percentage body fat. Bioelectrical impedance analysis is a reliable method of assessing body fat and has been strongly correlated ($r = 0.9$) with dual-energy X-ray absorptiometry.[25] Body mass index (BMI) was calculated from standing height and weight measurements.

Gross Motor Function Measure (GMFM) dimensions D (standing) and E (walking, running and jumping) were administered barefoot without assistive aids and the GMFM-66 score calculated using the Gross Motor Activity Estimator software.[26] GMFM-66 is a valid and responsive clinical tool designed to evaluate gross motor function for children with cerebral palsy.[27,28] The GMFM-66 has a linear, hierarchical structure with interval scaling; its psychometric properties including unidimensionality and item invariance are supported by Rasch analysis.[29]

The PODCI questionnaire, administered by parent proxy, documented status of their child within five domains including transfer and basic mobility; upper extremity and physical function; sports and physical function; pain and comfort; and happiness; and one global functioning scale that was the mean of all scales excluding happiness. The PODCI is primarily a measure of difficulty of physical functioning, but includes several questions related to participation. PODCI domains of upper extremity and physical function, pain and comfort, and happiness were not analysed separately for this study. Reliability, validity and responsiveness of the PODCI have been previously reported; construct validity is good; internal consistency and test–retest reliability are high with Cronbach's alpha >0.8 and $r > 0.8$, respectively.[30]

The distance travelled during the 1 minute walk test while using customary walking aids and orthoses was recorded. The 1 minute walk test is a proxy measure for functional ability and walking endurance that is discriminative among GMFCS levels.[31] Time to complete the Timed Up-and-Go[32] was recorded. The Timed Up-and-Go is a validated measure of functional mobility and balance modified to assess children with cerebral palsy; validity has been shown by good discrimination among GMFCS levels and correlates well with the GMFM.[32]

Multiple linear regression analyses were performed (SAS, version 9.3). Activity and participation measures, including GMFM-66, 1 minute walk test, Timed Up-and-Go, walking speed and PODCI were used as dependent variables. Measures of body structure and function were included as potential predictors (independent variables), including patient characteristics, gait impairment (Gillette Gait Index), body composition, and individual and aggregate muscle strength.

Analyses were stratified by GMFCS level. This approach was felt to provide better clinical insight not seen when GMFCS dominates the regression because of the variance shared with all independent and dependent variables, confounding interpretation of the results.[33] Eighteen regression models were generated and analysed for the six dependent variables at three GMFCS levels. The number of predictor variables introduced to each model was guided by a bootstrap analysis to identify most likely predictors.

Statistical analyses were performed using SAS version 9.3 software. Stepwise multiple linear regressions are criticized for overfitting models and overestimating variance explained. To address this concern, a parallel bootstrap analysis[34] was performed to independently estimate parameters and confidence intervals for each model. To avoid inclusion of multiple insignificant predictor variables in the regression models, a focused three-step approach was taken to identify potentially important predictors and then estimate and confirm the coefficients and percent variance explained by regression models for each outcome measure. First, a bootstrap analysis was performed with all predictor variables included for each dependent variable. Then, the subset of predictors selected at least 200 out of 1000 times were included in a multiple regression model to estimate the parameter coefficients, 95% confidence interval, and partial r-squares for each predictor. From the regression model, the partial r-square reflects the additional variance explained by each predictor variable when all other predictor variables

Table 1. Participant demographics by GMFCS level.

	Total	Level I	Level II	Level III
GMFCS level, *n* (%)	377 (100)	148 (39)	153 (40)	76 (28)
Cerebral palsy type, *n* (%)				
Hemiplegia	104 (28)	81 (54)	23 (15)	0 (0)
Diplegia	273 (72)	67 (45)	130 (85)	76 (100)
Gender, *n* (%)				
Male	241 (64)	91 (62)	107 (70)	43 (57)
Female	136 (36)	57 (38)	46 (30)	33 (43)
Birth history, *n* (%)				
<28 weeks	119 (32)	32 (22)	53 (35)	34 (45)
29–36 weeks	117 (31)	43 (29)	46 (30)	28 (37)
Full term	131 (35)	67 (45)	53 (35)	11 (15)
Unknown	10 (3)	6 (4)	1 (1)	3 (4)
Age of walking onset, months (SD)	28.2 (14.1)	20.1 (7.3)	31.9 (14.9)	36.1 (14.5)
Age, years (SD)	12.8 (2.7)	13.1 (2.8)	12.7 (2.7)	12.7 (2.6)
Height, cm (SD)	147.9 (14.7)	151.5 (15.0)	147.4 (14.0)	142.0 (13.4)
Weight, kg (SD)	44.9 (15.9)	46.4 (16.4)	44.5 (15.9)	42.9 (14.7)
BMI, mean (SD)	20.1 (4.9)	19.7 (4.6)	20.1 (5.3)	20.8 (4.7)
Body fat, % (SD)	26.4 (9.5)	25.7 (9.0)	26.2 (9.7)	28.1 (10.0)
Gillette Gait Index, mean (SD)	262.0 (182.9)	161.4 (108.7)	261.3 (155.1)	470.2 (183.2)

Frequency data for Gross Motor Function Classification System (GMFCS) level, cerebral palsy type (hemiplegia or diplegia), gender, birth history and mean (standard deviation) data for age of walking onset, age, height, weight, body mass index (BMI), body fat percentage and Gillette Gait Index are reported.

are already included in the model. Explained variance is the sum of the partial variances for all predictor variables. Finally, a second bootstrap analysis using this same subset of predictors was performed to confirm the parameter coefficients and 95% confidence intervals from the regression analysis.

Results

Of 748 patients screened, 273 did not meet inclusion criteria, 80 declined participation, and 18 were excluded for inconsistent or missing data, resulting in 377 participants. Participant demographics are reported in Table 1. The population was predominately caucasian (79%), reflecting the ethnic composition of children treated in the seven centres. No significant differences were seen across GMFCS levels for age, height or weight ($P > 0.05$). Age of walking onset ($P < 0.001$) and gestational duration ($P < 0.001$) varied by GMFCS level (Table 1) with greater severity being related to delayed walking onset and shorter gestation. Demographic characteristics of non-participants were not different from those of participants ($P > 0.05$).

Regression and bootstrap techniques produced highly similar results for estimated coefficients, confidence intervals, and variance explained (see Supplementary Table on the journal website). The combination of patient characteristics, strength, body composition and gait impairment explained at least 30% (r-squares are reported in Supplementary Table on the journal website) of the variability in scores for GMFM-66 (GMFCS levels I–III), walking speed (levels II and III), 1 minute walk test (level III), and PODCI transfer and basic mobility (levels I and III). The predictor variable that contributed most frequently to the regression models (15 of 18 models) was gait impairment measured by the Gillette Gait Index. When longer gestational

Table 2. Regression results: significant predictor variables ≥5%.

Outcome tools	GMFCS level	Predictor variables	Regression analysis			
			Coefficient	95% Confidence interval		Partial R^2
GMFM-66	I	Intercept	94.095	86.191	101.999	
		Age at walking onset	–0.326	–0.476	–0.175	0.119
		Gillette Gait Index	–0.018	–0.027	–0.008	0.118
	2	Intercept	76.801	73.407	80.194	
		Gillette Gait Index	–0.009	–0.015	–0.004	0.081
	3	Intercept	62.323	55.698	68.947	
		Gillette Gait Index	–0.015	–0.024	–0.006	0.160
		Gestation: >37 weeks	6.198	1.393	11.003	0.091
		Total extensors strength (knee @90)	–1.677	–3.315	–0.040	0.074
PODCI sports and physical function	I	Intercept	60.883	46.461	75.306	
		Cerebral palsy type: Hemiplegia	7.631	2.830	12.432	0.064
		Knee extensors strength (knee @30)	4.728	0.050	9.406	0.057
	2	Intercept	57.023	42.084	71.963	
		Hip abductor strength	5.236	0.701	9.771	0.063
	3	Intercept	52.794	31.995	73.592	
		Gestation: >37 weeks	17.705	7.381	28.029	0.187
PODCI transfers and basic mobility	I	Intercept	100.450	92.532	108.368	
		Gillette Gait Index	–0.029	–0.040	–0.018	0.182
	2	Intercept	74.782	64.575	84.989	
		No factors explained ≥5% variance				
	3	Intercept	66.158	44.113	88.203	
		Gestation: >37 weeks	22.719	12.146	33.292	0.180
		Gillette Gait Index	–0.041	–0.061	–0.021	0.163
Timed Up-and-Go	I	Intercept	4.183	2.219	6.147	
		Gillette Gait Index	0.004	0.001	0.006	0.089
	2	Intercept	6.247	3.897	8.598	
		No factors explained ≥5% variance				
	3	Intercept	9.076	–5.036	23.187	
		Gillette Gait Index	0.030	0.001	0.060	0.078
Walking speed	I	Intercept	106.765	93.839	119.690	
		No factors explained ≥5% variance				
	2	Intercept	109.067	86.391	131.744	
		Gillette Gait Index	–0.018	–0.035	–0.001	0.050
	3	Intercept	67.642	54.097	81.187	
		Gillette Gait Index	–0.031	–0.054	–0.009	0.147
		Hip extensor strength	–9.888	–16.284	–3.492	0.097

Table 2. (Continued)

Outcome tools	GMFCS level	Predictor variables	Regression analysis			
			Coefficient	95% Confidence interval		Partial R^2
1 minute walk test	1	Intercept	87.272	73.323	101.222	
		Gestation: 29–36 weeks	–10.069	–15.491	–4.647	0.074
	2	Intercept	80.471	67.657	93.285	
		Gillette Gait Index	–0.023	–0.040	–0.006	0.050
	3	Intercept	73.991	61.360	86.622	
		Gillette Gait Index	–0.045	–0.066	–0.024	0.202
		Knee flexor strength	7.491	0.083	14.900	0.139

Outcome tools, GMFCS level, predictor variables and the results from the regression (coefficient, 95% confidence interval, partial R^2) for each outcome measure stratified by GMFCS level. Regression predictor variables are significant based on $P<0.05$.
GMFCS, Gross Motor Function Classification System; GMFM-66, Gross Motor Function Measure; PODCI, Pediatric Outcomes Data Collection Instrument.

period and being female were significant predictors they were predictive of better scores on outcome measures. When higher Gillette Gait Index scores (increased gait impairment), older age at walking onset and higher percent body fat were significant predictors, they were predictive of worse scores. Individual and aggregate muscle strength scores had both positive and negative predictive effects on scores.

Predictor variables that explain more than 5% of variability in the outcome score are shown by GMFCS level in Table 2. Gait impairment was the most consistent predictor for all outcome tools and GMFCS levels, except PODCI sports and physical function (GMFCS level I–III), PODCI transfers and basic mobility (GMFCS level II), Timed Up-and-Go (GMFCS level II), walking speed (GMFCS level II) and 1 minute walk test (level I). Of the individual muscles assessed, no single muscle group was consistently a significant predictor. Individual muscle strength for hip abductor (PODCI sports and physical function; GMFCS level II), hip extensor (walking speed; GMFCS level III) and knee flexor strength (1 minute walk test; GMFCS level III) were the significant individual muscle predictors, yet only explained greater than 5% variability in one model each. Of the aggregate muscle strength measures, only total extensor strength was significant above 5% for GMFM-66 (GMFCS level III). Gestational age was significant for four models (GMFM-66, PODCI sports and physical function, PODCI transfers and basic mobility GMFCS level III and 1 minute walk test GMFCS level I). Age at walking onset was a significant predictor for GMFM-66 GMFCS level I.

Discussion

The amount of variability in scores on activity and participation measures in ambulatory children with cerebral palsy that can be explained by physical (body structure and function) predictor variables and personal characteristics were examined by GMFCS level. Gait impairment, measured using the Gillette Gait Index, explained the most variance and was the most common predictor explaining the greatest variance. Strength explained some variance but was not the primary predictor variable. Individual muscle strength findings were inconsistent within measures and among GMFCS levels. A minimal amount of variability was explained by body composition measures of BMI and percentage body fat. Patient characteristics of cerebral palsy type, gestational age and age at walking onset were significant predictor variables in several models and help explain additional variance.

The amount of variability explained in the activity and participation outcome scores by the body structure and function measures studied was not as

large as expected, despite the large sample size and a standardized prospective data collection protocol. Variability in outcome measure scores is multifaceted and can only be explained partially by strength and gait impairment. These findings may reflect a lack of direct relationships between impairment (body structure and function measures) and the activity and participation measures studied. Gillette Gait Index may have been identified as one of the best predictors of function because it is a more global measure of body structure and function than muscle strength, making it more similar to measures of activity and participation and therefore a better predictor of variance than strength. Other mediating factors such as services available to the patient and family, family structure, the external environment, among other factors, could contribute to the variation in physical function and help explain more of the variability in outcome scores. Other impairment-level predictor variables not measured in this study may have explained additional variance. Spasticity and selective motor control may have explained more variance in gait impairment and GMFM scores. Proprioception and postural control may have explained additional variance in Timed Up-and-Go. Additional variance in PODCI might be explained by environment and accessibility factors. This study further illustrates the challenges of attempting to explain variation within this population that is very heterogeneous even within GMFCS levels. Clinicians treating individuals with cerebral palsy should consider this when developing treatment paradigms. It is important to have interventions that target a variety of structure and function level impairments and to individualize treatment plans based on participant characteristics.

This study strengthened and expanded on previous research[10,11] by examining variance explained by participant characteristics, aggregate strength measures, body composition and gait impairment concurrently in a large cross-sectional sample of ambulatory children with cerebral palsy. Although the sample size was larger than previous studies and sufficient to stratify by GMFCS level, it was not large enough to stratify by cerebral palsy type concurrently. To address this, cerebral palsy type was added to the regressions.

Strength was assessed using a hand-held dynamometer, which is a more objective method than manual muscle testing, but has more inter-assessor variability than isokinetic dynamometers. Due to the inter-assessor variability the strength data was converted to *z*-scores, which precludes strength data from direct comparison to published strength values presented as force units, however this was not a primary goal of this study. While the statistical significant differences among assessors motivated the use of *z*-scores for the analyses, the variations among the assessors were minimal and demonstrated good face validity (for all assessors strength decreased significantly with increasing severity). Normalization of the strength data using *z*-scores optimizes the strength data collected and used in the analyses. Poor selective motor control during hand-held dynamometer testing and test positions that allow lower limb synergy patterns could potentially limit accuracy and reliability of the strength data. This is a limitation due to the population studied and demonstrates one of the challenges of assessing strength in this population. Despite these limitations this study was able to demonstrate when strength contributes to explaining variability in function measured by outcome tools.

The Gillette Gait Index was utilized to assess gait impairment since this study was undertaken prior to validation of the Gait Deviation Index.[35] The Gait Deviation Index may provide stronger associations with activity and participation scores since it has better statistical characteristics including a linear interval scale using more complete information from gait data compared to the Gillette Gait Index.[35]

Why body composition measures did not explain a larger percentage of variability in outcome scores is not clearly understood. These findings do not appear related to lack of variance in body composition data. Based on age- and gender-matched Center for Disease Control data,[36] 60% of the population was in the healthy weight category, 14% overweight and 14% obese. Body composition may have explained more variance if tasks requiring greater intensity and duration were assessed.

While strength findings were variable by measures and GMFCS level, the significant muscles identified were similar to those previously reported

by Ross and Engsberg[10] and Eek et al.[11] In the current study, hip abductor strength was predictive of higher scores at GMFCS level II for GMFM-66, PODCI transfers and basic mobility, and PODCI sports and physical function and at GMFCS level III for PODCI transfers and basic mobility. Knee flexor strength was predictive of higher scores for walking speed (GMFCS levels II and III) and 1 minute walk test (GMFCS III). Ross and Engsberg[10] reported that hip abductor, ankle plantar flexor and knee flexor strength were most predictive of GMFM-66 score. Eek et al.[11] found hip abductors and ankle plantar flexors most predictive of GMFM D score; knee flexors and hip abductors of GMFM E score and ankle plantar flexors and hip flexors were most predictive of GMFM-66 score.

Less gait impairment (lower Gillette Gait Index) was a significant predictor of higher scores on nearly all outcome measures. These findings are consistent with the clinical recognition that those with greater gait impairment have more difficulty with activity and participation. This relationship has previously been reported by Viehweger et al.,[37] who showed that Gillette Gait Index has a moderate inverse correlation to the GMFM and by Tervo et al.[18] who reported moderate to strong inverse correlations with log Gillette Gait Index and several PODCI domains.

Previous research has been inconclusive regarding the impact of gestational age on physical function.[38] The current study shows that gestational age explains some variance in the 1 minute walk test (level I), GMFM (levels II and III) and PODCI sports and physical function and transfers and basic mobility (level III). The relation of early gestational age and delayed age of walking onset to lower scores of activity and participation measures may reflect disease severity and indicate that, although children were stratified by GMFCS levels, there may be other characteristics that affect physical function.

Knowing the influence of each predictor variable on the outcome measure score can improve clinical care of individuals with cerebral palsy by guiding intervention and treatment plans and informing experimental designs to test treatment efficacy. The information gained from this study can provide direction to clinicians when designing treatment plans by identifying when strength and gait impairment are likely to play a role in physical functional tasks. Clinicians can refer to the Supplementary Table (on the journal website) to determine the influence of each predictor variable on the outcome measure score at a particular GMFCS level. For example, at GMFCS level I, GMFM-66 score = 94.095 – 0.326 *Age at walking onset (months) – 0.018 * Gillette Gait Index, where 94.095 is the intercept, and the coefficients are multiplied by the study measure. The current study results, analysed by GMFCS level, can help clinicians refine their treatments by considering different requirements based on impairment level. While patient characteristics are related to the type and severity of the central nervous system lesion and cannot be altered, they are important to consider when developing therapy goals and in discussions with families.

This study provides a foundation from which other investigators can develop hypotheses and research studies to help further explain the variability in physical function seen in ambulatory children with cerebral palsy. Future studies should examine whether changes in gait impairment, strength, body composition and personal characteristics are associated with changes in these outcome measures. The study results suggest treatments to reduce gait impairment, such as surgical intervention, orthotic management and/or physical therapy may have the greatest impact on physical function as measured using the studied outcome measures.

Clinical messages

- Gait impairment explained the most variance and was the most common predictor explaining variance in scores on activity and participation measures in ambulatory children with cerebral palsy.
- Strength measures help explains additional variance.
- Body composition measures did not help explain variance in scores on activity and participation measures.

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Conflict of interest

The author declares that there is no conflict of interest.

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