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BRIEF REPORT

Gait Deviation Index Correlates With Daily Step Activity in Children With Cerebral Palsy

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Abstract

Objectives: To examine the association between the Gait Deviation Index (GDI), a multivariate measure of overall gait impairment, and measures of both community walking performance and walking capacity within the clinic setting in ambulatory children with cerebral palsy.

Design: Cross-sectional study.

Setting: Gait analysis, 6-minute walk test (6MWT), and self-selected walking speed (WS) were conducted in laboratory and clinic settings. Activity monitoring was done in participants' community environment.

Participants: Children with cerebral palsy (N=55; age range, 6−18y) with Gross Motor Function Classification System levels I to III.

Interventions: Not applicable.

Main Outcome Measures: The GDI was derived from gait analysis data as a measure of overall gait impairment; an activity monitor was used to capture community walking performance, and the 6MWT and WS were the clinic-based measures of walking capacity.

Results: Fifty-five children had a median GDI of 78.86 (range, 53.07−105.34). A moderate association was found between the GDI and daily step count (Spearman ρ=.58; 95% confidence interval [CI], .37−.74; $P<.0001$). Weaker associations were found between the GDI and 6MWT (Spearman ρ=.4718; 95% CI, .2283−.6597; $P<.0003$) and between the GDI and WS (Spearman ρ=.3949; 95% CI, .1368−.6028; $P<.0028$).

Conclusions: The GDI has a moderate association with daily step count, which suggests that interventions that positively change gait kinematics may also affect community walking performance. Although the GDI's deviation from the normal value provides valuable information, other measures are required to provide a complete picture of a child's walking capacity and performance.

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Three-dimensional gait analysis (3-DGA) is a common assessment tool that is used in children with cerebral palsy (CP) to aid decision making before lower limb orthopedic surgery and to assess surgical outcomes.[1] However, the information obtained from 3-DGA is complex and requires skill to interpret. A number of tools have therefore been developed that derive a single representative score of gait impairment from 3-DGA data. One such example is the Gait Deviation Index (GDI).[2] The GDI is a dimensionless parameter based on 15 separate gait features that quantitates the extent to which the kinematic profile of a child with CP deviates from an average control data set.[2] It has concurrent validity with measures of motor performance in children with CP, including the Gillette Functional Assessment Questionnaire[2] and the Gross Motor Function Measure.[3] However, the association between the GDI and other measures of walking capacity and performance has not been investigated.

Walking capacity, or what a child can do in a controlled safe environment, is often assessed in the clinic by performing walk tests such as the 6-minute walk test (6MWT) and self-selected walking speed (WS) over 1 minute (in m/s). Both WS and 6MWT are reliable and valid measures of walking capacity in a child with CP.[4,5] Walking performance, or what the child does on a daily

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basis in the community, can be assessed by monitoring with accelerometers. One such monitor is the StepWatch activity monitor,[a] a waterproof, microprocessor-linked accelerometer worn on the ankle, which has established criterion validity in this population.[6] Measures captured by the StepWatch activity monitor include total step count per day, percentage of time inactive, and percentage of time spent in low, medium, or high activity (<15, 15−42, >42steps/min for 1 leg).[6]

The present study aimed to examine the association between the GDI and measures of both community walking performance (daily step count, level of activity) and walking capacity within the clinic setting (self-selected WS, 6MWT) in ambulatory children with CP.

Method

Participants

The study was approved by the national and regional ethic committees. Inclusion criteria were as follows: all children with CP, aged 6 to 18 years, who functioned at Gross Motor Function Classification System (GMFCS) levels I to III,[7] and who were undergoing a clinically indicated 3-DGA. Children were excluded if they had significant illnesses, injury, or surgery within the past 6 months that may have affected the usual activity levels in the community; were unable to complete 3-DGA; or had planned treatment after 3-DGA, which did not allow them to wear the monitor for a week. Written consent was obtained from each child's parent or guardian and assent from each child.

Procedure

On the day before 3-DGA, a 6MWT was conducted using a 25-m circuit, asking the child to walk at a self-selected speed and allowing rest periods over the 6 minutes, according to standardized guidelines.[8] 3-DGA data were captured using a Qualisys Oqus system and processed with Qualisys Track Manager[b] and Visual 3D software.[c] Data capture occurred during the middle (4m) of a level 8-m walkway; a minimum of 5 representative trials were averaged to derive self-selected WS and 3-dimensional kinematics.

The StepWatch activity monitor was fitted on the day of 3-DGA and preprogrammed to each participant by specifying the participant's height and gait characteristics. Step detection accuracy was tested by manually correlating the triggered flashes from the internal light-emitting diode light with the steps taken when the participant was asked to walk for a short period at different speeds. Greater than 95% step detection accuracy was achieved for all participants. Participants were instructed to wear the monitor for all waking hours for the next 7 days, except when bathing or swimming, and then to return the monitor by post to the principal investigator. All data capture was completed during the school term and school days used for the analysis.

List of abbreviations:

3-DGA	**3-dimensional gait analysis**
6MWT	**6-minute walk test**
CI	**confidence interval**
CP	**cerebral palsy**
GDI	**Gait Deviation Index**
GMFCS	**Gross Motor Function Classification System**
WS	**walking speed**

Data analysis

Each participant's GDI was calculated from a representative gait cycle for both the left- and right-hand sides. The mean of the 2 sides was used for the analysis as advocated by Sangeux et al.[9] The first 2 complete weekdays of accelerometer data (ie, those closest to the date of 3-DGA) were used to define the average daily step count and levels of activity as recommended by Rich et al.[10] A day was defined as at least 10h/d of recorded activity with no longer than 2 hours of zero data capture. The StepWatch activity monitor captures step activity of a single leg; so, the step counts were doubled to obtain the total step count.

Statistical analysis

The level of association between the GDI, average daily step count, 6MWT, WS, and levels of activity was tested using the Spearman correlation coefficient (ρ) calculated with GraphPad InStat 3.10.[d] A multiple linear regression analysis performed with R 3.0.2[e] and SAS 9.4[f] was used to examine the association between total step count and the GDI. Participants functioning at GMFCS level III were excluded from the analysis on the advice of the statistician because of the small group size. The analysis was adjusted for confounding variables that included age, sex, GMFCS level, and bilaterality of CP.

Results

A total of 69 participants were recruited into the study. However, 7 children (10%) did not record any activity data on their monitor and a further 7 (10%) did not have data sufficient to meet the a priori definition of a day. Fifty-five of the 69 participants (80%) were thus included in the final analysis. Children included in the final analysis were similar to those excluded, in terms of sex, age, and GMFCS level (table 1). For the 55 participants with 2 complete days of accelerometer data, the median daily step count was 10,468 (range, 1686−17,263). Just over half of the participants (n = 30; 55%) had a step count of >10,000steps/d, with 14 of 16 participants (88%) functioning at GMFCS level I meeting this target but only 16 of 32 participants (50%) functioning at GMFCS level II meeting this target.

Table 1 Demographic characteristics of participants

Characteristic	Participants Recruited Into Study (n=69)	Participants With Complete Data Capture (n=55)
Age (y)	11 (6−18)	11 (6−16)
Sex: F, M	33, 36	26, 29
GMFCS level: I, II, III	22, 37, 10	16, 32,7
Bilateral CP	38	32
GDI	78.86 (51.88−105.34)	78.86 (53.07−105.34)
6MWT (m)	459 (200−698)	481 (200−698)
WS (m/s)	1.00 (0.34−1.36)	1.00 (0.34−1.32)

NOTE. Values are median (range) or as n.