ORIGINAL ARTICLE

Test-Retest Reliability of Discrete Gait Parameters in Children With Cerebral Palsy

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ABSTRACT. Klejman S, Andrysek J, Dupuis A, Wright V. Test-retest reliability of discrete gait parameters in children with cerebral palsy. Arch Phys Med Rehabil 2010;91:781-7.

Objectives: To examine the test-retest reliability of discrete gait parameters in children with cerebral palsy (CP) in Gross Motor Function Classification System (GMFCS) levels I, II, and III; to calculate the measurement error between testing sessions of these parameters in the total sample and within GMFCS subgroups using the standard error of measurement; and to evaluate the minimal detectable change (MDC) to identify discrete gait parameters that are most sensitive to change in children with CP.

Design: Test-retest reliability study.

Setting: Rehabilitation facility with human movement laboratory.

Participants: Ambulatory children with CP (N=28).

Interventions: Not applicable.

Main Outcome Measures: Intraclass correlation coefficients (ICCs), standard error of measurement, and MDC of discrete gait parameters.

Results: Parameters measured in the sagittal plane and temporal-spatial parameters were highly reliable across all GMFCS levels (ICC range, .84–.97), while test-retest reliability in the frontal and transverse planes varied from poor to excellent (ICC range, .46–.91). Using MDC as a guide, hip and pelvis parameters in the transverse and frontal planes were least responsive for GMFCS levels I and III (MDC ranges, 8.3°–18.0° and 2.7°–23.4°, respectively), whereas ankle kinematics were the least responsive for level II (MDC range, 8.2°–11.9°). Reliability was dependent on mobility level, with children in GMFCS level III exhibiting greater test-retest variability overall.

Conclusions: Our findings suggest that select discrete gait parameters measured using computerized gait analysis are reliable and potentially responsive measures of performance and can be used as outcome measures in intervention studies.

Key Words: Cerebral palsy; Rehabilitation.

COMPUTERIZED GAIT ANALYSIS is commonly used in the assessment of gait deviations in children with CP.[1-4] However, observed changes in CGA measurements may be more attributable to variability associated with the measure than to actual functional change. The 3 primary sources of measurement error that contribute to the day-to-day variability with observational measures such as CGA are variations in performance of the child, measurement error of the instrumentation, and measurement inconsistencies of the examiner administering the test.[5] Prior to use in clinical evaluation, it is essential to understand all sources of variability inherent to CGA to determine whether the data collected are representative of the person's gait pattern and whether the chosen parameters are consistent enough between testing sessions to allow meaningful clinical decision-making and to evaluate clinical change over time.

CGA produces large quantities of information, and to simplify the analysis and facilitate interpretation, discrete gait parameters such as maximum knee flexion and hip ROM are typically extracted from the continuous kinematic waveforms.[6,7] Previous work has shown that the intrasession variability of these discrete gait parameters increases inversely with function in children with CP as measured by the GMFCS.[6] Sampling a number of stride repetitions was recommended from this work; specifically, a minimum of 4 strides was specified for children in GMFCS level I and a minimum of 6 strides for children in GMFCS levels II and III.

No studies to date document the day-to-day repeatability of discrete gait parameters measured using CGA in children with CP. Instead, previous reliability work in this population has evaluated the measurement of the underlying kinematic waveforms.[8,9] Findings suggested that kinematic variables can be reliably measured using CGA; however, intrasession reliability was generally higher than intersession (test-retest) reliability.[8,9] The intersession repeatability of discrete gait parameters is critical information for outcomes work. Estimates of measurement error facilitate accurate sample size calculations for outcome studies and provide guidance for the choice of gait parameters that are sensitive to change. Previous work investigating the reliability of discrete gait parameters has focused on able-bodied adults.[10,11] Typical results included mean difference between visits of select parameters and the corresponding SDs of the difference scores, which have been informative in identifying repeatable gait parameters in able-bodied adults. In general, reliability was higher for ankle and knee parameters than parameters measured at the hip and pelvis.[10,11]

In this context, the objectives of the current study were to (1) examine the test-retest reliability of discrete gait parameters

List of Abbreviations

CGA	computerized gait analysis
CI	confidence interval
CP	cerebral palsy
GMFCS	Gross Motor Function Classification System
ICC	intraclass correlation coefficient
MDC	minimal detectable change
MSE	mean square error
ROM	range of motion
SEM	standard error of measurement

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obtained through CGA in children with CP in GMFCS levels I, II, and III; (2) calculate the measurement error between testing sessions of these parameters in the total sample and within GMFCS subgroups using the SEM; and (3) evaluate the MDC to identify discrete gait parameters that are most sensitive to change in children with CP.

METHODS

A longitudinal single group study was conducted with a baseline and retest session. The retest interval was 1 to 2 weeks and a maximum retest period of 3 weeks was allowed. Actual changes in gait function would not be expected in this period in the absence of intervention.

Participants

A convenience sample of 28 children with CP was recruited for the study from physiotherapy outpatient caseloads. Parents who had children who met the basic eligibility criteria were given study information letters by their physiotherapist. Those who expressed an interested in learning more about the study then had their names passed to the research assistant on the research team, and the informed consent process followed from there according to the study's Research Ethics Board-approved protocol. The children's characteristics are summarized in table 1. Ten children were in GMFCS level I (9 boys, 1 girl), 10 were in GMFCS level II (4 boys, 6 girls), and 8 were in GMFCS level III (4 boys, 4 girls). Most participants used lower-limb orthoses regularly, but the gait trials were collected in the barefoot walking condition to optimize marker placement and viewing of joint angles. Seven of the children in GMFCS level III walked with a walker, and 1 used bilateral quad canes. Subjects were excluded if they had received botulinum toxin A injections in the lower limbs within the last 3 months or any orthopedic surgery or neurosurgery in the last 6 months. Prior to participation, all procedures were explained to the child, and informed written consent was obtained from the parent or guardian as approved by the research ethics board at our facility.

Procedure

Details of the data collection procedure are provided elsewhere[6] but are briefly described here. Participants wore spandex shorts and a tank top during data collection to minimize marker movement artifact. Reflective markers were placed on anatomic landmarks on the pelvis and bilaterally on the thighs, shanks, and feet. The markers were applied on all subjects by the same evaluator, who had 5 years of experience evaluating the gait of children with CP. Participants were instructed to walk along a walkway at their self-selected comfortable walking speed. Each child took 2 practice walks prior to the commencement of data collection. A minimum of 3 passes was collected for each subject. Data were collected using a Vicon MX motion[a] capture system sampling at 120Hz. Reflective markers were manually identified using a Vicon Workstation.[a] Data were processed to determine spatiotemporal and kinematic parameters using Bodybuilder software.[a] The same protocol was repeated at retest.

Data Analysis

Twenty-nine discrete gait parameters were selected for test-retest analysis from those commonly used in clinical outcome studies done on this population.[6,12-14] Custom-written Matlab[b] programs were used to extract relevant features from the kinematic curves.

To ensure that a stable intrasession measure was obtained for each discrete gait parameter, 6 repeated measures of each gait parameter were averaged for each subject for each of the 2 visits.[6] Parameters were extracted from 2 consecutive midwalk strides of gait for each of the 3 gait passes. The impact of using this combination of intrapass and interpass strides was investigated in a previous study[6] and did not confound the results.

Data were analyzed unilaterally. For children with hemiplegia, data were analyzed for the affected side, whereas the side of the body was arbitrarily chosen for the children with spastic diplegia.

Statistical Analysis

The between-session reliability was calculated using the ICC measuring agreement ($ICC_{2,1}$)[15] and associated 95% CI. For the purpose of analysis, mean ICC values of .80 and above reflected excellent reliability, those between .70 and .79 indicated good reliability, and those below .70 reflected poor to moderate reliability.[5] Analyses were completed with all participants and within GMFCS levels I, II, and III.

The SEM calculates the total measurement error across repeated measures resulting from performance differences in the child as well as instrument and assessor variability. The SEM was calculated using the MSE from 2-way analysis of variance[16-19] where $SEM=\sqrt{MSE}$. This formulation of the SEM has been recommended[17] rather than using calculations based on the ICC statistic because it is unaffected by the range of measurement values (ie, extent of variation in the sample). The MDC was also calculated to estimate the minimal amount of change that is needed to exceed measurement error. The MDC was calculated by multiplying the SEM by $\sqrt{2}$ and the z score associated with the desired level of confidence.[16,20] An MDC confidence level of 90% was chosen for the current study because this level is often used in clinical outcome studies in children with disabilities.[21-23]

Bland-Altman plots were constructed for each parameter to estimate measurement bias. Plots were constructed by plotting the mean difference between visits against the mean of the 2 visits.[24] Plots were examined for the magnitude of the difference between visits and the distribution around the 0 line. The

Table 1: Participants' Characteristics

GMFCS Level	Diagnosis	Age (y)*	Height (cm)	Mass (kg)
I (n=10)	1 with spastic triplegia 2 with spastic diplegia 7 with hemiplegia (6 left, 1 right)	6.6±2.9	122.7±13.9	26.0±8.9
II (n=10)	9 with spastic diplegia 1 with hemiplegia (1 left)	8.1±2.1	126.7±14.7	31.8±11.9
III (n=8)	8 with spastic diplegia	7.3±3.0	115.9±12.1	27.0±6.2

NOTE. Values are mean±SD.
*The ages between the 2 groups did not differ significantly (P=.439).