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Gait pathology subtypes are not associated with self-reported fall frequency in children with cerebral palsy

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ABSTRACT

Background: Trips and falls are common concerns reported by parents of children with cerebral palsy. Specific gait pathologies (excessive internal hip rotation, intoeing, and stiff knee gait) are anecdotally associated with higher rates of falls.

Research question: Is fall frequency higher for the aforementioned gait pathologies?

Methods: Parent-reported fall frequency from 1063 children with cerebral palsy who also had a three-dimensional gait analysis was retrospectively reviewed. Frequency of 10 common gait pathologies was determined and fall frequency for the gait pathologies of interest were compared to matched control groups. Possible effects of Gross Motor Functional Classification System (GMFCS) level and age on fall frequency were also assessed and matched in the control group, as appropriate.

Results: In general, parent-reported fall frequency increased from GMFCS level I to II and then decreased until level IV. Moreover, younger children tended to report greater fall frequency, though children who reported never falling were of similar age as those who reported weekly falls, resulting in an inverted-U shaped relationship. Children with cerebral palsy who walked with excessive internal hip rotation, excessive intoeing, or stiff knee gait did not report increased fall frequencies compared to other children with cerebral palsy matched on GMFCS level and age that did not walk with those gait patterns. Approximately 35% of children reported never falling, 35% reported falling daily, and 30% reported falling monthly or weekly for each gait pattern. Therefore, elevated fall frequency appears to be a generic problem for most children with CP rather than a function of a specific gait pattern.

Significance: Clinicians should be aware of these relationships, or lack thereof, when trying to decipher the cause of a child's falling and when determining appropriate interventions. Future studies may seek to more objectively quantify fall frequency, as self-report is the main limitation of this study.

1. Introduction

Many children and adults with cerebral palsy (CP) walk with non-typical gait patterns, which are often deemed problematic. For instance, it is nearly ubiquitous for articles to state that internal hip rotation (IHR) and/or intoeing in children with CP may result in increased risk for trips or falls [1–11]. Tripping or falling presumably occurs because the swing foot may catch on the interfering stance shank or foot. While logical, there is no evidence for such a claim, but this claim is one justification for an external femoral derotation osteotomy and/or tibial derotation osteotomy to correct intoeing. Stiff knee gait (SKG) is another gait pattern commonly asserted to result in increased trip or fall prevalence due to inadequate foot clearance during the swing phase of gait [12–14], but again, evidence is lacking.

Since patients with CP generally suffer from deficient muscle strength [15–17], selective muscle activation [18], balance [19], and/or proprioception [20], it is fathomable that the clinical assertion of increase fall frequency among these specific gait pathologies may actually reflect base-rate neglect [21]. In other words, individuals who score poorly in the aforementioned areas will tend to trip or fall more often compared to typically developing. Individuals with CP may represent one example of this, as they report higher fall frequencies [22,23]. This high base-rate prevalence may be overlooked when mentally classifying typical fall frequency of a patient who walks with IHR, intoeing, or SKG, because it may be assumed that fall frequency is high because of his/her gait pathology rather than deficiencies generally associated with the CP diagnosis. Therefore, our purpose was to test the hypothesis that fall frequency will be higher among children with CP who walk with IHR, intoeing, and SKG versus other gait patterns.

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2. Methods

This was a retrospective study in which fall frequency was extracted from medical records for all patients < 18 years old diagnosed with cerebral palsy who visited Gillette Children's Specialty Healthcare for a three-dimensional gait analysis. The University of Minnesota Institutional Review Board approved the study and granted waiver of consent. Data from September 1, 2009 through April 13, 2017 were included, which is when our Gillette Functional Assessment Questionnaire [24] first included specific questions for parents/guardians to indicate fall frequency at their child's clinical gait analysis. The questions were:

1a. Does the patient fall more often than typical for age/level of activity?
a. Yes b. No c. No, because of constant supervision
1b. If yes, how often?
a. 1x/month b. 1x/week c. 1–2x/day d. Multiple times/day

Any barefoot gait analysis data collected as part of routine clinical appointments or research studies were queried from the same time period. Routine clinical data collection included three barefoot walking trials at self-selected speed while collecting three-dimensional kinematics.

2.1. Data analysis

The average of the walking trials was used to determine whether a patient's gait pattern met the definition of commonly identified gait pathologies (Table 1). Gait pathologies were defined as kinematics exceeding two standard deviations (SD) of our typically developing (TD) reference data [25], unless otherwise noted. Patients' kinematics could have met the definition of no, one, or more than one gait pathology. Only one limb was analyzed, and if a patient had multiple visits, one visit was randomly selected for analysis to assure independence of observations.

Fall frequency data were simplified from six categories to four to reduce relatively redundant categories and increase statistical power. Specifically, 'never' and 'never, due to constant supervision' were combined; and '1–2x/day' and 'multiple times/day' were combined. These four categories roughly translate to falling never, monthly, weekly, or daily.

2.2. Statistical analyses

We hypothesized that GMFCS level and age are associated with fall frequency (i.e., falls may be less prevalent for children of GMFCS III and IV who use assistive devices, and falls may be more prevalent for younger children), so we first performed a chi-square test and logistic regression (proportional odds model), respectively, to check these assumptions. Both factors were independently associated with fall frequency. As such, each gait pathology of interest (IHR, intoeing, SKG) was analyzed separately to determine if GMFCS level or age differed between that gait pathology and its control group (e.g., if 200/1000 patients had IHR, fall frequency of 200 vs. 800 was compared). For GMFCS, a chi-square test was performed. For age, differences were analyzed using Wilcoxon rank sum tests and non-parametric effect sizes [29], with effect sizes ≥ |0.5| considered significant as they would roughly correspond to medium or larger effect sizes in parametric terms.

Next, a resampling method was employed to extract a more well-matched control group for the gait pathologies of interest for which GMFCS and/or age were significantly different from its control group (method details in Supplemental material). Briefly, the resampling method found the proportion of data that fell within given distribution bins of GMFCS for the target gait pathology group (e.g., IHR, intoeing, or SKG) and matched the proportion of data falling into those bins by randomly selecting appropriate subsamples from its control group.

Table 1
Gait pathology definition, prevalence, and patient demographics.

Gait pathology	Definition	N (%)	Age Median [IQR]	GMFCS level (%)					Prior treatment (%)[a]	Prior surgery (%)
				I	II	III	IV	unknown		
Crouch	> 2 SD more than TD for knee flexion at initial contact (15.2°) and minimum knee flexion (18.3°) [26]	361 (34.0)	10.8 [6.9]	13	38	38	9	2	83.1	59.0
Excessive anterior pelvic tilt	Mean anterior pelvic tilt over the entire gait cycle > 2 SD more than TD (21.4°)	317 (29.8)	9.4 [6.8]	19	32	40	7	1	80.8	59.9
None[b]		249 (23.4)	10.6 [5.4]	65	29	6	0	1	58.6	40.6
Outtoeing	Mean external foot progression angle in stance > 2 SD more than TD (−19.6°)	231 (21.7)	10.6 [5.4]	19	34	34	11	2	85.3	63.2
Intoeing	Mean internal foot progression angle in stance > 2 SD more than TD (8.0°)	163 (15.3)	7.5 [5.7]	20	40	31	7	2	73.6	45.4
Stiff knee gait	At least 3 out of 4 criteria [27]: 1) ≥ 2 SD below TD peak swing knee flexion (49.5°) 2) ≥ 2 SD below TD knee flexion range of motion during initial swing (17.7°) 3) ≥ 2 SD below TD total knee range of motion (48.7°) 4) ≥ 2 SD more than TD time of peak knee flexion as a percent of swing phase (42.7%)	163 (15.3)	11.2 [5.9]	5	38	41	15	1	84.1	60.1
Equinus	Continuous plantarflexion (< 0°) throughout stance [28]	135 (12.7)	6.3 [3.3]	13	30	46	12	0	80.7	37.0
Calcaneal gait	Mean dorsiflexion in stance > 2 SD more than TD (14.2°)	113 (10.6)	11.9 [5.8]	15	30	42	11	2	82.3	70.8
Excessive hip adduction	Mean hip adduction in stance > 2 SD more than TD (10.9°)	109 (10.3)	11.4 [6.4]	19	31	43	6	0	83.5	64.2
Excessive internal hip rotation	Mean hip rotation in stance > 2 SD more than TD (18.5°)	96 (9.0)	11.2 [7.2]	21	36	35	7	0	88.5	69.8
Recurvatum	Knee extension in stance > 2 SD below TD (−6.3°)	62 (5.8)	7.1 [4.1]	10	42	44	5	0	91.9	64.5

SD: standard deviation, TD: typically developing.
Note that patients' gait pattern could meet the definition of more than one gait pathology, so ΣN ≠ 1063.
[a] Includes surgical and non-surgical interventions (e.g., botulinum toxin, casting).
[b] Kinematics did not meet any gait pathology definition; does not imply that all patient's kinematics fell within ± 1 SD of TD gait.