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Gait characteristics, balance performance and falls in ambulant adults with cerebral palsy: An observational study

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ABSTRACT

The relationship between spatiotemporal gait parameters, balance performance and falls history was investigated in ambulant adults with cerebral palsy (CP). Participants completed a single assessment of gait using an instrumented walkway at preferred and fast speeds, balance testing (Balance Evaluation Systems Test; BESTest), and reported falls history. Seventeen ambulatory adults with CP, mean age 37 years, participated. Gait speed was typically slow at both preferred and fast speeds (mean 0.97 and 1.21 m/s, respectively), with short stride length and high cadence relative to speed. There was a significant, large positive relationship between preferred gait speed and BESTest total score ($\rho = 0.573$; $p < 0.05$) and fast gait speed and BESTest total score ($\rho = 0.647$, $p < 0.01$). The stride lengths of fallers at both preferred and fast speeds differed significantly from non-fallers ($p = 0.032$ and $p = 0.025$, respectively), with those with a prior history of falls taking shorter strides. Faster gait speed was associated with better performance on tests of anticipatory and postural response components of the BESTest, suggesting potential therapeutic training targets to address either gait speed or balance performance. Future exploration of the implications of slow walking speed and reduced stride length on falls and community engagement, and the potential prognostic value of stride length on identifying falls risk is recommended.

1. Introduction

Information regarding mobility and balance performance of people with a range of health conditions is valuable in determining level of function, change in function over time and health outcomes. Measures of gait performance are suited for this purpose as they have been shown to be particularly sensitive to change [1]. In older adults, slower preferred gait speed has been associated with an increased falls risk [2] and overall survival [3]. A reported gait speed of 1.2 to 1.3 m/s is considered necessary to be a successful community ambulator [4]. A usual gait speed of less than 1 m/s has identified persons at high risk of negative health related outcomes such as imminent hospitalisation in well-functioning older people [3]. In specific populations such as persons with stroke, people who cannot walk faster than 0.84 m/s six months post stroke, are unlikely to be walking independently in the community [5]. Gait speed can provide useful information about health outcomes and potential community participation.

Spatiotemporal gait variables and, more specifically, measures of gait variability, have been proposed as independent contributors to balance dysfunction and falls risk in older adults [6]. For example, increased intra-individual variability in step length and double support phase have been associated with increased risk of multiple falls in older adults [7] and extreme step width variability has been associated with falls history in older persons [8]. There have been inconsistent findings regarding significance of associations between spatiotemporal gait variables and balance performance in people with neurological dysfunction. In those with early Parkinson's disease a reduction in gait speed and stride length has been associated with impaired dynamic balance performance [9], however no significant association was found between gait speed

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or stride length and measures of upright stability in Friedrich's ataxia [11]. In those with Parkinson's disease who fall, stride-to-stride variability is increased [10], yet a recent review article exploring gait variability in those with multiple sclerosis was unable to demonstrate a link between measures of gait variability and falls in this population [12]. Evidence of significant associations between spatiotemporal gait variables, gait variability and balance performance in adults with cerebral palsy (CP) has the potential to direct future clinical management of this population.

With the recent increased attention on the lifespan health care needs of those ageing with developmental disability, there has been greater focus on falls experienced by adults with CP. Of concern, evidence suggests that this population fall frequently, with reports of more than 60% of cohorts falling per year [13,14]. However, research on the relationships between gait characteristics, balance performance and falls history are only just emerging. A preliminary study found better balance performance, assessed with the Berg Balance Scale, to be associated with higher levels of gross motor function in ambulant adults with CP [13], however no significant relationship was evident between balance performance and falls. Further research has indicated high variability in balance performance [14] and kinematic gait variables [15] in ambulant adults with CP who frequently fall, however associations between balance and falls, as well as between gait variables and falls were not examined. Given the established value of gait measures in describing falls risk in other populations, the aims of this study were to explore the relationship between gait characteristics, balance performance and falls history in ambulant adults with CP.

2. Method

Ethical approval was gained (12206B) and registration with the Australian & New Zealand Clinical Trials Registry (ACTRN12613000166774). All participants provided written informed consent.

2.1. Participants

Participants were recruited through advertisements placed in outpatient clinics and organisations that support people with disability, and through previous contact (prior five years) with Clinical Gait Analysis Service at Monash Health, Australia, as part of a randomised controlled trial exploring efficacy of a balance training intervention [16]. Participants had a diagnosis of any subtype of CP [17], were 18 years or older, and ambulant with or without a walking aid (Gross Motor Function Classification Scale—Extended and Revised Levels I-III; GMFCS-E&R [18]).

2.2. Outcome measures

Participants were characterised according to age, gender, GMFCS-E&R Level, and CP subtype.

Gait measurements were recorded by a computerized walkway system, the GAITRite® (CIR Systems Inc., USA). The GAITRite® electronic walkway contains 27 sensor pads with an active area of 61 cm (wide) by 792 cm (long). Data were collected at a 120 Hz sampling frequency. The GAITRite® is valid and reliable in measuring gait in people with neurological conditions and normative comparison groups [19,20]. Measures of gait speed, stride length (right and left step length), step width and cadence were determined at both self-selected preferred and fast walking speeds, directly from footfalls on the instrumented walking surface. Stride length was calculated from the geometrical centre of the heel of one footprint to the next ipsilateral footprint. Step length was calculated along the horizontal axis from the geometric centre of one heel to the next contralateral footprint. Step width was calculated from the line perpendicular to the line of progression between the geometrical centres of the heel of two consecutive footprints.

Participants started and finished walking 2 m before and after the mat to allow for acceleration and deceleration. Any partial footfalls that did not have clearly defined beginning and ending or were in contact with the edge of the instrumented walking surface were removed. After a practice trial to become accustomed to the walking surface and testing environment, each participant completed three consecutive preferred and three consecutive fast-paced walking trials. For the fast trials, participants were instructed to walk as fast as they safely could.

Balance performance was assessed using the Balance Evaluations Systems Test (BESTest) [21]. The BESTest is a clinical balance assessment tool, previously used to provide insight into balance performance in ambulant adults with CP [14]. It aims to identify balance dysfunction in six different components of balance control: (I) biomechanical constraints; (II) stability limits/verticality; (III) anticipatory postural adjustments; (IV) postural responses; (V) sensory orientation; and (VI) stability in gait. Balance performance is recorded on a 4-level ordinal scale (0–3, 0 = cannot perform, 3 = normal performance) for each component. A total sum is calculated, converted to percentage score (0–100%), with higher scores reflecting better balance performance and lesser balance dysfunction. Sub-scores are also recorded for each of the six components.

Falls recalled in the previous 12 months was collected in an interview with the participant and/or carer, and categorised into non-faller (0 falls) or faller (1 or more falls).

2.3. Data analysis

The SPSS statistical software version 22.0 (SPSS Inc, Chicago, Illinois) was used for all quantitative analysis. All continuous variables were analysed for distribution and skewness. Mean values for walking speed (m/s), stride length (m), step width (m), and cadence (steps/min) were described for both preferred and fast gait speed conditions. Double support time as a percentage of gait cycle, and differences between preferred and fast gait speed conditions were calculated. Due to potential asymmetry in step lengths, steps were categorised within individuals as either the longer step or shorter step. Variability in step length, step width and double support time were calculated using the standard deviation (SD) of all steps for the respective measure from the three preferred and three fast gait speed trials. Pearson correlation coefficients (r) were calculated to determine the relationship between preferred and fast gait speeds. Spearman rank order correlations (rho) were calculated to determine the relationship between gait variables and measures of balance (BESTest). The strength of any relationships was described as small (0.10–0.29), medium (0.30–0.49) or large (0.50–1.0) [22]. Independent *t*-tests were used to examine differences between fallers and non-fallers on balance and gait variables.

3. Results

Seventeen adults (10 males) with CP participated, mean age 37 years (range 19–53 years). Fourteen were spastic CP subtype (5 unilateral and 9 bilateral) and 3 had other subtypes (2 mixed, 1 ataxic). Two participants were GMFCS-E&R Level I, ten were GMFCS-E&R Level II, and five were GMFCS-E&R Level III. Seven participants used a walking aid; two used four-wheeled walkers, four used forearm crutches and one used a single point stick.

Gait characteristics at preferred and fast speeds are reported in Table 1. The mean stride length at preferred speed was 0.69 m (0.28), increasing only slightly at fast speed to 0.77 m (0.33). The