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Impairments of balance, stepping reactions and gait in people with cervical dystonia

Christopher Barr[a], Rhiannon Barnard[b], Lauren Edwards[b], Sheila Lennon[b], Lynley Bradnam[b,c,*]

[a] Clinical Rehabilitation, School of Health Sciences, Flinders University, Australia
[b] Discipline of Physiotherapy, School of Health Sciences, Flinders University, Australia
[c] Discipline of Physiotherapy, Graduate School of Health, University of Technology Sydney, Australia

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ABSTRACT

Background: Impaired balance is common in neurological disorders. Cervical dystonia is a neurological movement disorder affecting the neck. The effect of this aberrant head posture on physical function is unknown.
Objectives: To compare balance, mobility, gait and stepping reactions between ten people with cervical dystonia and ten control adults.
Methods: Spatiotemporal gait parameters and walking speed were assessed using a computerised walkway. Step length and time, time in double support and gait variability were calculated, then normalised to gait speed. Centre of pressure path length was assessed with eyes open and eyes closed to calculate a Romberg Quotient. Simple and choice reaction times were measured using customised apparatus while mobility was assessed by the timed up and go. Cervical spine range of motion was measured using a head mounted goniometer. Self-reported scales included Falls Self Efficacy Scale and Dystonia Discomfort Scale.
Results: There was a difference between groups for most outcome measures. The timed up-and-go and walking speed was slower (both $P < 0.005$) and the Romberg Quotient lower ($P = 0.046$) in cervical dystonia. People with cervical dystonia had lower falls self-efficacy ($P = 0.0002$). Reduced cervical range of motion was correlated with balance, stepping reaction time and mobility (all $P < 0.05$). Timed up and go was positively associated with stepping reaction time ($P < 0.01$). Dystonia discomfort did not impact function.
Conclusions: People with cervical dystonia displayed deficits in balance, gait and stepping reactions, and expressed higher fear of falling. Studies to further elucidate functional limitations and their impact on activity and participation in daily life are required.

1. Introduction

Dystonia is a poorly understood but relatively common neurological movement disorder; the third most prevalent movement disorder after Parkinson's disease and essential tremor [1]. Cervical dystonia (CD) is an isolated dystonia characterised by sustained and involuntary contractions of neck muscles, resulting in non-functional neck and head postures [2,3]. The pathophysiology of CD involves multiple brain structures, including sensorimotor cortex, basal ganglia, cerebellum, trigeminal and vestibular nuclei and is considered a brain network disorder [4–7]. People living with neurological movement disorders commonly display poor postural control, impaired mobility and balance when walking, turning and transferring and delayed stepping reactions [8–11]. Impairments in balance are known to influence gait and slow walking speed [12–14] and may lead to falls in those with neurological disorders and in older adults [15,16].

Clinically people with CD often report that fear of falling curtails their physical activity [17]. To date there is little understanding as to whether people with CD experience balance and gait deficits, even though they are known to have issues with proprioceptive and vestibular function [18–21] and impaired vision secondary to the twisted head posture. Growing evidence for the involvement of the cerebellum in CD suggests there may be an impact on balance and function given the importance of the cerebellum in motor coordination and gait. People with CD are known to walk at slower speeds than healthy controls [22], have low falls self-efficacy and balance confidence [17,22]. The primary aim of this study was to compare balance, gait and stepping reactions in people with CD with control adults. Secondary aims were to explore if abnormal head posture, dystonia severity or fear of falling impacted on function.

* Corresponding author at: Discipline of Physiotherapy, University of Technology Sydney, PO Box 123, Ultimo, NSW 2007, Australia.
E-mail addresses: lynley.bradnam@uts.edu.au, lynley.bradnam@flinders.edu.au (L. Bradnam).

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2. Methods

This study was a point in time observational study of people diagnosed with CD by a neurologist, and of age and sex matched healthy adults. Participants provided written informed consent and the study was approved by the local Human Research Ethics Committee. Participants were included whether or not they underwent regular treatment with botulinum toxin injections and, as we did not specify a specific time point in their treatment cycle, time (weeks) since the last injections was recorded. To control for this variation, people with CD completed the Dystonia Discomfort Scale (DDS) [23] to record the degree of discomfort associated with their dystonia (0% no discomfort, 100% maximal discomfort) on the day of the study. There was no exclusion criteria based on current medications. Exclusion criteria were; the use of gait aids, the inability to walk unaided for 20 m, an antalgic/pathologic gait pattern and a neurological or musculoskeletal condition affecting the lower limbs. Participants were also excluded if previously diagnosed with a separate disorder known to affect balance, such as peripheral vascular disease, vestibular disorders or tinnitus, cerebellar dysfunction or visual deficits not corrected by wearing lenses. Participants attended a motion analysis laboratory for a single experimental session lasting approximately 30 min.

Participants completed the following functional assessments. Spatiotemporal gait analysis used the GAITRite walkway (CIR Systems Inc, New Jersey, USA), a 4.9 m × 0.6 m long walkway with embedded pressure sensors sampling at 120 Hz to record footfalls. Participants were required to walk at their self-selected comfortable walking speed 6 times, incorporating an additional 2 m at the beginning and end to ensure that steady speed walking was recorded. Each participant completed the Timed Up and Go (TUG) test [24], where they were asked to rise from a chair, walk round a mark 3 m in front of them, and return to a seated position. Time taken from the initiation of movement to returning to a seated position was recorded and averaged over 3 trials. For balance, the Centre of Pressure (CoP) path length during quiet stance was recorded using a Humac Balance Board (CMSi Solutions, MA, USA) under the conditions of eyes open (EO) and eyes closed (EC). Each condition was presented twice in a random order, and the Romberg Quotient (RQ) was calculated as the ratio of EC/EO. The Humac Balance Board has been shown to be as accurate as a force plate to assess postural sway in a standard motion analysis laboratory [25]. Simple reaction time (RT) of the hand and foot were recorded by a custom made device (Physiological Profile Assessment tool [26]), with reaction time (ms) recorded by pressing a switch with either the dominant finger or foot in response to a light stimulus. For each measurement, five practice trials were allowed for familiarisation, followed by 10 experimental trials. Choice stepping reaction time was assessed using a modified dance mat and customised software in a protocol previously reported [27]. Participants were required to step on to the corresponding pad of the dance mat in response to a stimulus presented on a computer screen. After a practice trial of each stepping direction, four trials for each pad (24 trials total) were presented in a random order for each leg. The time taken to lift the foot from the mat after the stimulus was determined as the decision time and the time taken to step on the correct arrow on the mat was determined as the response time. Cervical range of motion (ROM) was measured using a head mounted C-ROM Goniometer (Performance Attainment Associates, USA). The C-ROM 3 is located to anatomical landmarks on the head with inclinometers zeroed to the frame to allow accurate assessment of ROM in 3 planes. Two goniometers (flexion-extension and lateral flexion) made use of a ball technology to enhance accuracy of measurement, and the third (rotation) used a compass to measure head ROM in reference to the shoulders. All participants competed the Falls Self-Efficacy International Scale (FES-I) [28] to determine fear of falling.

2.1. Data processing and statistical analysis

GAITRite mat spatiotemporal parameters of gait speed, step time, step length and double support time were extracted and averaged for each participant. Gait variability was assessed by calculating the coefficient of variation (CoV) using the mean and standard deviation (SD) of each spatiotemporal parameters to determine a unitless measure comparable across studies. To control for differences in walking speed, spatiotemporal parameters and their corresponding coefficient of variation values were normalised to walking speed by dividing the parameter by walking speed [29]. For CoP the average values of total mediolateral, anteroposterior, and total path length sway in mm were recorded under EO and EC conditions. To assess the visual impact on postural sway, a Romberg Quotient (RQ) was calculated by dividing path length of EC over EO [30]. Higher RQ indicate greater visual dependence for postural control. Reaction time for the hand and foot were separately averaged. To assess stepping reactions the decision and response times were separately averaged for the ipsilateral (i.e. the side of the body aligned with the direction of tonic head turn) and contralateral sides. Prior to analysis, the ipsilateral and contralateral sides for people with CD, and dominant and non-dominant side for controls, were compared for all measures using paired *t*-tests. As all results showed no significant differences, the two sides were collapsed into a single measure for each outcome prior to statistical analysis.

Statistical analysis was conducted using SPSS v22 (IBM, Chicago). For all data, normality of distribution was confirmed by analysis of Z-scores for skewness and kurtosis. Separate independent *t*-tests were used to compare groups for all outcome measures, with alpha set to 0.05 for all comparisons. Pearson's correlations were used to separately investigate relationships for cervical ROM, DDS and FES-I and each functional outcome measure. Secondary analysis using Pearson's correlations was then conducted to probe associations between walking speed, TUG, and balance with the other functional measures. As this study was exploratory, no formal adjustments were made for multiple correlations; however for the correlation analyses alpha was set to 0.01 to reduce type II errors.

3. Results

Ten people with CD (9 female, mean age 53.9 ± 12.6 years) and 10 gender and age matched controls (mean age 52.8 ± 12.2 years) were included in the study. Seven of the people with CD had a cervical tilt bias to the left. The average duration of disease from diagnosis was 12.1 ± 9.7 years. Eight of the ten participants were undergoing treatment by botulinum toxin injections at the time of the study; the average time post-injection on the day of the study was 5.9 ± 2.8 weeks. No participants reported taking other medications for their CD at the time of the study. The mean score on the DDS was 64.5% (range 45%–85%, SD 14.0), indicating on average there was moderate discomfort on the day of the trial. People with CD presented with reduced neck range of motion in all directions (all $P < 0.031$) and reported a higher fear of falling ($P = 0.001$) than control adults. The mean score and statistical significance for each outcome measure is presented in Table 1.

3.1. Gait parameters

People with CD walked more slowly than controls (CD group 116.2 ± 20.7m/s, control group 141.8 ± 12.9 m/s; $P = 0.004$). When corrected for walking speed, people with CD demonstrated longer step time ($P = 0.004$) and step length ($P = 0.014$) and spent longer in double support ($P = 0.009$) compared to the control group. When corrected for walking speed, people with CD demonstrated higher step time variability ($P = 0.0004$), lower step length variability ($P < 0.0001$) and lower variability in the time spent in double support ($P = 0.023$).