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Original Research

Effects of Attentional Loadings on Gait Performance Before Turning in Stroke Survivors

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Abstract

Background: Attentional loadings have significant impacts on turning performance in individuals with stroke. Improper gait modification before turning may contribute to falls after stroke. Therefore, examination of the changes in temporal-spatial gait parameters before turning may reveal important deficits in gait control when stroke survivors are challenged by dual-tasking.
Objective: To compare the effects of 3 attentional loading conditions on spatial-temporal gait parameters before turning between stroke survivors and healthy control subjects.
Design: Case-control study design.
Setting: University motion analysis laboratory.
Participants: Ten chronic stroke survivors (mean age = 49 ± 9 years) and 10 healthy control subjects (mean age = 53 ± 5 years) were included.
Methods: Spatial-temporal gait parameters were obtained by the use of a motion-capture system while participants performed the Timed-Up and Go (TUG) test under 3 attentional loading conditions: single, dual-motor, and dual-cognitive task conditions. A repeated-measure analysis of variance was used to analyze the data.
Main outcome measures: We measured gait speed, stride length, and stride time during the straight walking phase (one gait cycle before turn) of the TUG test.
Results: We found that attentional loadings had a differential effect on gait speed measured for both groups ($P = .001$). The dual-motor and dual-cognitive task conditions led to a slower gait speed compared with the single-task condition in stroke survivors (both $P = .02$). However, in the TUG scores of healthy control subjects, only the dual-cognitive condition led to a significantly reduced gait speed compared with the single task condition ($P = .001$) and dual motor condition ($P = .01$).
Conclusion: The results demonstrated that attentional loadings resulted in a greater deterioration of gait performance before turning in stroke survivors compared with healthy control subjects. Particularly, temporal gait parameter was more vulnerable to dual-task interference than the spatial gait parameter.

Introduction

Turning during walking is an attention-demanding task among healthy individuals that involves a sequence of deceleration of gait speed, adjustment of gait parameters, and reorientation of body segments [1-3]. A previous study reported that both anterior-posterior and medial-lateral ground reaction forces change before an individual turns to slow down the walking speed [4]. Step lengths and step widths became asymmetric to redirect the center of mass (COM) toward the new direction [2]. A successful turn, therefore, requires an integrated control of multiple systems, including motor, sensory, and postural control. Thus, individuals with gait difficulties, such as survivors of stroke, often struggle to perform turning tasks safely and are at high risk of falls.

The Timed Up and Go (TUG) test is a popular clinical tool to assess balance and mobility in various populations. The TUG test measures the time taken for an individual to stand up from a chair, walk 3 m, turn 180°, walk 3 m back to the chair, and sit down [5]. Previous studies had used the TUG test to capture turning difficulty and identified 4 indicators of turning difficulty: staggering or loss of balance while turning, absence of pivoting during turning, taking 5 or more steps to complete the turn, and taking 3 seconds or longer to complete the turn [6,7]. Furthermore, the TUG test consists

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of dual-task testing conditions [8,9]. Dual-task performance in the TUG test involves carrying out the primary task (ie, walking) and a secondary task simultaneously. The concurrent performance of an attentional demanding task and the walking task often deteriorates gait performance, secondary task performance, or both. Therefore, the dual-task TUG test further challenges gait stability, and thus, may provide a more comprehensive assessment of balance capacity.

We have demonstrated previously that stroke survivors took a longer time and more steps to complete the TUG under the dual-task conditions [10]. However, it was not clear such changes were caused by stroke or aging, because we did not include an age-matched control group in our previous study. We also showed that stroke survivors responded differently to attentional loadings during straight walking compared with turning. We found that straight walking phase of the TUG test was influenced by both types of secondary task (motor and cognitive). However, only the secondary motor task, but not the secondary cognitive task, increased the time taken to complete the turning phase of the TUG test.

Furthermore, we noted that the stroke survivors walked slower and with interrupted steps as they were approaching the turning area under the dual-task conditions. Therefore, dual-tasking might have substantially and differentially alter gait parameters in straight walking and turning. However, this observation could not be verified because we did not record the gait performance with a motion analysis system that would allow us to determine the associated changes in gait parameters.

A previous study has shown that adjustment of gait parameters before turning was critical for a successful turning in patients with Parkinson disease [11]. Furthermore, capability to adjust gait parameters before turning often is compromised in diseased populations. For example, patients with cerebellar ataxia approached turns with a shorter step length and wider stride width compared to healthy adults [12]. Similarly, stroke survivors were found to be more temporally asymmetric relative to healthy participants when approaching turns [13]. These findings suggest that examination of the gait parameter modification before turning may reveal important deficits that contribute to falls during turning. Accordingly, the objective of this study was to compare the effects of attentional loading on gait performance before turning during the TUG test between stroke survivors and age- and gender-matched healthy control subjects. Particularly, we used a detailed biomechanical analysis to extend our previous work to reveal the potential gait deficits in stroke that cannot be captured by performance-based measures. We hypothesized that attentional loadings would lead to a greater effect on gait parameters for stroke survivors compared with their matched healthy control subjects.

Methods

Participants

Ten stroke survivors (5 male, 5 female) and 10 healthy control participants (5 male, 5 female) participated in this case-control cross-sectional study. A power analysis in which the authors used a previous study that compared the TUG performance between healthy controls and individuals with stroke [13] showed that an estimated sample of 20 participants would provide 80% power with a risk of type 1 error of 0.05. Stroke survivors were recruited from a government-funded hospital using a purposive sampling. Healthy control subjects were recruited from the local community and matched to the stroke participants by age and gender. The inclusion criteria for participants with strokes were as follows: at least 6 months poststroke with a unilateral hemiplegia; of an age ranging between 30 and 70 years of age; able to walk independently and continuously for 10 m without any walking aids; able to walk while holding a glass full of water with the nonaffected hand; able to follow one-step commands; and able to perform simple arithmetic calculations. Both stroke survivors and healthy control subjects were excluded if they had more than one incidence of stroke, other neurologic disorders (eg, Parkinson disease or traumatic brain injury) or orthopedic conditions (eg, joint deformities, osteoarthritis or rheumatoid arthritis). They also were excluded if they had visual field defects determined by confrontation visual field examination or scored less than 24 on the Mini Mental State Examination (MMSE). All participants signed an informed consent form approved by the institutional ethics committee before their participation.

Procedure

We recorded each participant's demographic and medical information and measured their performance on the MMSE and Berg Balance Scale (BBS) [14]. For individuals with strokes, we also measured their motor impairments using the Fugl-Meyer Assessment Lower Extremity motor function test (FMLE) [15]. The BBS consists of 14 items that evaluate balance in different activities [14]. Each item is scored on a 5-point scale (0-4) with a maximum total score of 56 (a greater score indicates better balance). A cut-off score of 45 predicts the risk of falls [16]. The Fugl-Meyer is a validated measure for voluntary movement control after stroke. The lower extremity subscale (FMLE) consists of 17 items and each item is scored on a 0-2 scale (total score range, 0—34) [15]. A lower score on the FMLE represents a more severe lower limb motor impairment.

The experiment was conducted in a university-based motion analysis laboratory. A 3-m walkway was marked on the floor with a Kistler force plate (Kistler Holding AG, Winterthur Switzerland) placed at the end of the