Gait & Posture 44 (2016) 89–93

Contents lists available at ScienceDirect

Gait & Posture

journal homepage: www.elsevier.com/locate/gaitpost

Association of trunk control with mobility performance and accelerometry-based gait characteristics in hemiparetic patients with subacute stroke

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ARTICLE INFO

Article history:
Received 27 March 2015
Received in revised form 31 August 2015
Accepted 17 November 2015

Keywords:
Accelerometry
Biomechanical phenomena
Cerebrovascular disorders
Postural balance
Rehabilitation

ABSTRACT

Trunk control plays an important role in movement control and postural balance during functional activities. The purpose of this study was to investigate the association of trunk control early after stroke with mobility performance and quantitative gait characteristics derived from trunk accelerations. Fifteen patients with hemiparesis following stroke (median age, 61 years [range, 56–78 years]; median time since stroke, 9 days [range, 7–15 days]) participated in this cross-sectional observational study. Subjects were evaluated using the Trunk Impairment Scale (TIS), the short-form of the Berg Balance Scale (SF-BBS), an isometric knee extension strength test, the Timed Up and Go test (TUG), and a timed walking test. The linear acceleration of the lower trunk was recorded along the 3 axes during walking and quantified using the autocorrelation coefficient and harmonic ratio to assess the variability and smoothness of upper-body movement. The TIS total score had a significant correlation with TUG time. The coordination subscale score of the TIS was significantly correlated with TUG time, walking speed, and accelerometry variables in univariate analysis. The TIS coordination subscale score was significantly related to accelerometry variables in the partial correlation analysis adjusted for SF-BBS score and knee extension strength on the paretic and nonparetic side. These results indicate that trunk motor impairment after stroke is closely associated with poor mobility performance and trunk instability in gait. These findings support intensive rehabilitation treatment targeting trunk control to regain better mobility and stable gait in patients early after stroke.

1. Introduction

Stroke and cerebrovascular disease are leading causes of morbidity, mortality, and disability, and are the most common cause of the need for long-term care in Japan [1]. As well as upper- and lower-extremity impairments, trunk motor impairment also arises from stroke and follows the time course of the recovery [2,3]. Trunk control plays an important role in movement control and postural balance during functional activities. Previous studies have demonstrated that trunk control after stroke is closely associated with functional balance and activities of daily living [4–6], and is an important predictor of functional recovery [7–9]. These results suggest the importance of intensive rehabilitation treatment targeting trunk control after stroke. Several randomized controlled studies have investigated the effects of trunk exercises in people with stroke, as highlighted in a recent systematic review [10]. Saeys and colleagues [11] showed that the effects of trunk exercises transferred to improved standing balance and mobility in addition to improved trunk performance.

Impaired mobility is one of the most common symptoms of stroke, and falls often occur during walking in the community setting after hospital discharge [12]. Therefore, regaining independent mobility with a safe and stable gait pattern is one of the main goals of stroke rehabilitation. Although the relation between trunk performance and mobility has been studied in non-acute and chronic stroke patients [4], it has not been studied in the early phase of stroke. In addition, it has recently been reported that, in older adults [13,14] and persons with musculoskeletal or neurological disorders such as transtibial amputation [15],

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http://dx.doi.org/10.1016/j.gaitpost.2015.11.011
0966-6362/

Parkinson's disease [16], and stroke [17], gait characteristics derived from trunk acceleration, such as stride regularity, variability, and smoothness, are more sensitive to the risk of falling than typical gait characteristics such as gait speed and cadence. However, there are no studies that have investigated the associations between trunk performance and accelerometry-based gait characteristics in individuals following stroke.

The purpose of the present study was to investigate the association between trunk control and mobility performance and quantitative gait characteristics based on trunk accelerometry in patients with subacute stroke. We hypothesized that trunk motor control early after stroke would be independently related with mobility performance and accelerometry-based gait characteristics. Knowledge of the association of trunk control with mobility performance and accelerometry-based gait characteristics would provide valuable information for designing appropriate rehabilitation therapy programs to improve gait function following stroke.

2. Methods

2.1. Participants

This was a cross-sectional observational study performed between January and December 2013 in the rehabilitation center of an acute care hospital. This study was approved by the ethics committee of the hospital, and all participants gave informed consent.

Eligible patients with subacute stroke who were medically stable and underwent inpatient rehabilitation were recruited. Inclusion criteria were: (1) first ever stroke with unilateral hemiplegia and (2) able to walk 15 m without physical assistance from another person. Exclusion criteria were: (1) aged younger than 50 or 80 and older; (2) musculoskeletal or neurological conditions other than stroke that could interfere with gait; and (3) unable to understand the instructions because of communication or cognitive problems.

2.2. Procedures

Demographic and clinical characteristics were obtained from medical records. All clinical assessments were made by a trained physical therapist. Stroke severity was assessed with the National Institutes of Health Stroke Scale (NIHSS), which is a widely used measurement of stroke-related neurological deficits and has excellent intra- and inter-rater reliability [18].

Trunk performance was measured using the Trunk Impairment Scale (TIS) [19]. The TIS contains 3 subscales: static sitting balance (3 items), dynamic sitting balance (10 items), and coordination (4 items), which have a maximum score of 7, 10, and 6, respectively. The total TIS score can range from 0 to 23, with higher scores indicating better trunk performance. Intra- and inter-rater reliability and concurrent validity of the TIS have been established in a stroke population [19].

Balance and lower-extremity motor function were assessed as possible confounders. Balance was evaluated using the short form of the Berg Balance Scale (SF-BBS) [20], which is a 7-item performance measurement tool that tests static and dynamic balance in the standing position and during a sit-to-stand movement. Each item of the SF-BBS is scored on a 3-point scale (i.e., score of 0, 2, or 4), and the total score ranges from 0 to 28, with a greater score indicating better balance. The 7-item SF-BBS with the 3-point scoring scale has excellent reliability and validity in poststroke patients [20]. Lower-extremity motor function was assessed by knee extension strength. Knee extension strength is closely correlated with functional activity performance in individuals with stroke [21]. The isometric force exerted by the knee extensors of the paretic and nonparetic limbs was measured using a handheld dynamometer (μ-tas F-1; ANIMA Corp., Tokyo, Japan). During testing, subjects were seated with the hip and knee flexed to 90° and were required to perform 2 maximum voluntary isometric contractions. The maximal force of the 2 trials was multiplied by the moment arm to calculate joint torque, and then was normalized to body weight. The test–retest reliability of knee extension strength was calculated using the intraclass correlation coefficient (ICC) and was excellent, with an ICC(1,1) of 0.97 (95% confidence interval [CI], 0.92–0.99) and 0.99 (95% CI, 0.96–1.00) for the paretic and nonparetic side, respectively.

Mobility performance was assessed using the Timed Up and Go test (TUG) and walking speed. In the TUG, the time required to rise from an armchair, walk 3 m at a comfortable pace, turn around, return to the chair, and sit down was measured in seconds by a digital stopwatch. To assess walking speed, participants walked a distance of 15 m at their preferred comfortable speed. The time taken to walk the middle 10 m was measured by a digital stopwatch and used to calculate walking speed. These mobility tests were performed barefoot, and subjects were allowed to use a single-point cane and/or an orthosis if necessary. Subjects performed each test twice. The test–retest reliability was excellent, with an ICC(1,1) of 0.98 (95% CI, 0.95–0.99) and 0.95 (95% CI, 0.86–0.98) for the TUG and walking speed, respectively. The average of the 2 trials was used in the analysis.

2.3. Trunk accelerometry gait analysis

The linear acceleration of the lower trunk was recorded along the anteroposterior (AP), mediolateral (ML), and vertical (VT) axes during the 2 trials of the timed walking test using a wireless accelerometer (WAA-006; Wireless Technologies Inc., Tokyo, Japan; size, $39 \times 44 \times 12$ mm; weight, 20 g) that contained a tri-axial piezoelectric acceleration sensor (H30CD, Hitachi Metals Ltd., Tokyo, Japan; acceleration range, ± 4 g; 12-bit digital output). The accelerometer was attached to the lower back at the level of the L3 spinous process, near the body center-of-mass, with an elastic band. The acceleration data were digitized and sampled at a rate of 200 Hz, and stored on a personal computer via a Bluetooth wireless link.

2.4. Data processing

Each acceleration time-series was filtered by a second-order Butterworth bandpass filter with cutoff frequencies of 0.1 and 20 Hz [17]. Steps were identified by the characteristic sharp peaks in the AP acceleration, which corresponds to initial contact, as previously reported by Zijlsta [22]. Acceleration data from 5 consecutive strides in the middle part of the walkway were quantified separately in all 3 axes using the unbiased autocorrelation coefficient (AC) and the harmonic ratio (HR), according to previous reports [23,24]. These variables are associated with fall incidence in older adults and individuals with gait disturbances [13–16] and with hemiparetic severity and functional outcomes in people with stroke [25,26].

The AC is used as an indicator of stride regularity and variability of trunk acceleration. The AC is computed by correlating the overlapping parts of the time-series with a replication of the same time-series that had been phase shifted by the average stride time and ranges from 0 to 1, with 0 indicating no association and 1 indicating perfect replication of the gait cycle signal between neighboring strides [13,23]. The test–retest reliability of the AC was good, with an ICC(1,1) of 0.81 (95% CI, 0.53–0.93), 0.88 (95% CI, 0.69–0.96), and 0.80 (95% CI, 0.51–0.93) for the AP, ML, and VT axis, respectively. The average of the 2 trials was used in the analysis.

The HR provides an indicator of the smoothness and rhythmicity of trunk acceleration patterns. The HR is based on