Disability and Rehabilitation Assistive Technology

http://informahealthcare.com/idt
ISSN 1748-3107 print/ISSN 1748-3115 online

Disabil Rehabil Assist Technol, Early Online: 1–4
 DOI: 10.3109/17483107.2014.932019

informa healthcare

RESEARCH PAPER

Correlations between Berg balance scale and gait speed in individuals with stroke wearing ankle–foot orthoses – a pilot study

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Abstract

Purpose: The Berg balance scale (BBS) is commonly used to assess balancing ability in patients with stroke. The BBS may be a good candidate for clinical assessment prior to orthotic intervention, if it correlates well with outcome measures such as gait speed. The purpose of this study was to investigate the correlation between the BBS measured prior to walking with an ankle-foot orthosis (AFO) and specific temporal-spatial parameters of gait when walking with an AFO donned. *Methods*: Eight individuals with chronic stroke participated in this study. Balancing ability was assessed using the BBS, while temporal–spatial parameters of gait (gait speed, bilateral step length, stride length and step width) were measured using a three-dimensional motion analysis system. The correlations between the BBS and gait parameters were investigated using a non-parametric Kendall's Tau (τ) correlation analysis. *Results*: The BBS showed correlations with gait speed ($\tau = 0.64$, $p < 0.05$), the step length of the affected side ($\tau = 0.74$, $p < 0.05$), and the stride length ($\tau = 0.64$, $p < 0.05$). *Conclusions*: Assessment of the BBS prior to AFO prescription may potentially help clinicians to estimate the gait speed achievable following orthotic intervention in patients with stroke.

➤ Implications for Rehabilitation

- Assessment of the BBS prior to AFO prescription may help orthotists to estimate the gait speed following an orthotic intervention in patients with stroke.
- Assessment of the BBS prior to AFO prescription may help orthotists to understand overall balance and postural control abilities in patients with stroke.
- A larger scale multifactorial analysis is warranted to confirm the results of this pilot study.

Keywords

Ankle–foot orthosis, Berg balance scale, hemiplegia, posture, walk

History

Received 27 January 2014
Revised 16 April 2014
Accepted 3 June 2014
Published online 23 June 2014

Introduction

Stroke affects the motor system as well as parts of the sensory system which influence balancing ability, such as central vestibular function, proprioceptive perception and visual perception [1]. Impairment of postural control in patients with stroke affects functional performance in undertaking activities of daily living (ADLs) and also adversely affects their gait [2]. In a systematic review, the Berg balance scale (BBS) has been shown to have excellent intra- and inter-rater reliability as well as test–retest reliability when applied to the stroke population, and it has been noted to be correlated with measurements of gait speed in patients with hemiplegia [3]. The BBS is sensitive to change and has a large effect size [4], and it also correlates well with ambulatory activity levels in patients with chronic stroke and also gait speed in elderly people [5,6]. Thus, it may be considered as a reliable measure of balancing ability. Measurement of gait speed has been associated with detection of clinically important changes and can differentiate various categories of community ambulation [7,8]. Therefore, it is a primary parameter of assessment when studying gait in patients with stroke.

Ankle-foot orthoses (AFOs) are commonly prescribed for patients with hemiplegia and weak ankle dorsiflexion as they have been shown to improve their gait speed and balance [9,10]. AFOs are generally classified as articulated or non-articulated, although the evidence when to use articulated versus non-articulated AFOs is limited and requires further investigation [11]. Prior to prescribing AFOs, orthotists perform clinical assessments, such as testing muscle strength and assessing specific ranges of motion. Utilization of the BBS as a routine assessment prior to AFO prescription may also prove to be useful as a clinical assessment tool in orthotic intervention for stroke patients. However, the association between the BBS scores prior to wearing an AFO and temporal-spatial parameters of gait when individuals with hemiplegia ambulate with an AFO *in situ* is not well documented. Orthotists can understand the general balance

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and postural control abilities of the patients through the 14 assessment items of the BBS, and they can also relate its score with potential gait outcome in patients with stroke prior to orthotic intervention if their correlations are demonstrated. The hypothesis of this study was, therefore, that BBS scores obtained for hemiplegic individuals prior to wearing an AFO would correlate with temporal-spatial parameters of gait, such as walking speed and step length on the affected side when ambulating with an AFO *in situ* on the affected lower limb.

Methods

Participants

Eight individuals [eight males; aged 39 (SD 9) years] who had suffered from a stroke for more than six months [16 (SD 11) months; duration span of 8–40 months] participated in this study (Table 1). Inclusion criteria were: (1) the ability to walk independently with an AFO, (2) hemiplegia as a result of a single stroke, (3) the existence of a single foot-drop and (4) an ability to communicate well. Individuals with previous history of other neurologic or orthopedic conditions, which could affect the results of the study, were excluded. Six participants wore a non-articulated AFO, while two participants wore an articulated AFO. All AFOs were made of thermoplastic with a posterior leaf spring design and full-length footplate. The AFOs used in this study were those previously prescribed for the volunteer participants. The study was approved by the Human Subjects Ethics Committee of The Hong Kong Polytechnic University and a consent form was obtained from each participant.

Measurement of BBS and gait parameters

The balancing ability of each participant was evaluated using the BBS while not wearing an AFO. This was done to simulate the clinical situation where it is performed as part of an assessment prior to AFO prescription and fitting. The BBS consists of 14 balance assessment items including: (1) sitting unsupported, (2) sitting to standing, (3) standing to sitting, (4) transfers, (5) standing unsupported, (6) standing with eyes closed, (7) standing with feet together, (8) tandem standing, (9) standing on one leg, (10) turning trunk (feet fixed), (11) retrieving objects from floor, (12) turning 360 degrees, (13) stool stepping and (14) reaching forward while standing. Each item carries four points, and its total is 56. A copy of BBS form can be downloaded from The Internet Stroke Center (http://www.strokecenter.org/professionals/stroke-diagnosis/stroke-assessment-scales/).

Gait analysis was conducted with a three-dimensional motion analysis system (MAC3D system, Motion Analysis, Santa Rosa, CA) with six infra-red digital cameras (Hawk Digital, Motion Analysis, Santa Rosa, CA). The sampling rate of the cameras was set at 120 Hz. All data were fed into the motion analysis software (EVaRT 4.6.5, Motion Analysis, Santa Rosa, CA) for processing. Gait analysis was conducted when a participant walked with the previously supplied AFO. Each participant was instructed to walk at a self-selected walking speed at least three times. Temporal-spatial parameters, including gait speed, bilateral step length, stride length and step width, were calculated from the displacement of retro-reflective markers located on the posterior aspect of the bilateral heels while walking a 10-m walkway in the gait laboratory. Each parameter was calculated as an average of at least eight gait cycles.

Statistical analysis

Statistical analyses were conducted using SPSS version 16.0 for windows (SPSS Inc., Chicago, IL). The non-parametric Kendall's Tau correlation analysis was carried out to detect a correlation (Kendall's Tau rank correlation coefficient $= \tau$) between the BBS and temporal-spatial parameters of gait because the BBS scores were ordinal data. Those parameters which showed a significant level at $p < 0.05$ and had the correlation coefficient (τ) of 0.6 or higher were considered to have a correlation.

Results

Individual results of the BBS and temporal-spatial parameters of gait are shown in Table 2. Gait speed ranged from 0.22 m/s to 1.10 m/s with a mean of 0.67 (SD 0.28) m/s. The BBS ranged from 33 to 56 with a mean of 43 (SD 7). The BBS showed correlations with a gait speed ($\tau = 0.64$, $p < 0.05$), step length of the affected side ($\tau = 0.74$, $p < 0.05$), and stride length ($\tau = 0.64$, $p < 0.05$) (Figure 1).

Discussion

The purpose of this study was to investigate the correlation between the BBS measured while not wearing an AFO and temporal-spatial parameters, while walking with an AFO. The BBS demonstrated significant correlations ($\tau = 0.64$, $p < 0.05$) with gait speed. They also revealed a correlation with the step length of the affected side ($\tau = 0.74$, $p < 0.05$) and the stride length ($\tau = 0.64$, $p < 0.05$). This would be due to the relationship between gait speed and step/stride length. The BBS scores were not measured while participants wore their AFO as this study was designed to inform the efficacy of the BBS in correlating with gait speed, which may be expected from walking with an appropriately-prescribed AFO prior to a patient's AFO prescription. The results of this study suggested that assessment of the BBS prior to AFO prescription may not only help orthotists to understand patients' overall balance and postural control abilities but it may also help them to estimate gait performance when an appropriately-prescribed AFO is supplied in the course of rehabilitation of patients with stroke.

Table 1. Demographic data of the individuals with stroke.

Participant	Gender (F/M)	Age (year-old)	Height (cm)	Weight (kg)	Hemiplegic side (L/R)	Time since stroke (months)	Type of stroke	AFO
1	M	51	169	60	R	12	Hemorrhagic	AAFO
2	M	34	181	70	L	23	Hemorrhagic	NAAFO
3	M	36	167	62	R	10	Ischemic	NAAFO
4	M	49	170	73	L	11	Hemorrhagic	NAAFO
5	M	41	159	65	R	40	Hemorrhagic	NAAFO
6	M	44	168	64	L	13	Hemorrhagic	AAFO
7	M	23	172	59	R	13	Hemorrhagic	NAAFO
8	M	36	170	68	R	8	Hemorrhagic	NAAFO
Mean (SD)	8M	39 (9)	170 (6)	65 (5)	3L/5R	16 (11)	–	–

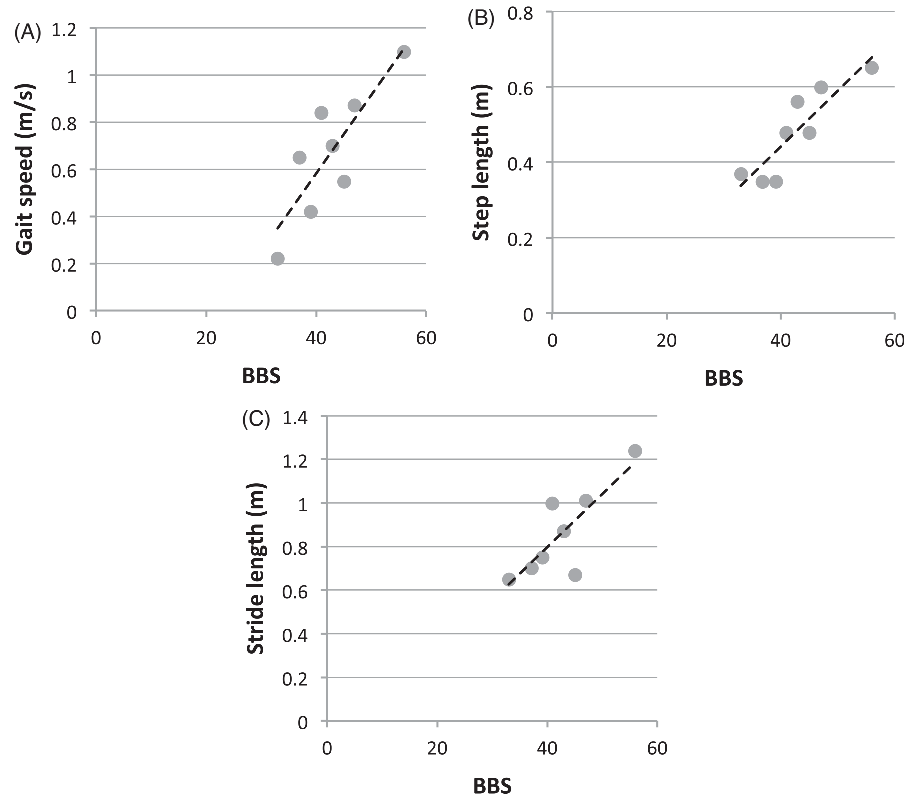
AAFO or NAAFO: articulated AFO or non-articulated AFO, L: left, M: male, R: right, SD: standard deviation.

Table 2. The BBS and the temporal-spatial parameters of gait in each participant.

Participant	BBS	Gait speed (m/s)	Step length (affected) (m)	Step length (non-affected) (m)	Stride length (m)	Step width (m)
1	37	0.65 (0.03)	0.35 (0.01)	0.35 (0.03)	0.70 (0.03)	0.15 (0.02)
2	43	0.70 (0.05)	0.56 (0.04)	0.31 (0.04)	0.87 (0.07)	0.10 (0.03)
3	41	0.84 (0.04)	0.48 (0.06)	0.52 (0.02)	1.00 (0.06)	0.10 (0.04)
4	33	0.22 (0.02)	0.37 (0.04)	0.28 (0.03)	0.65 (0.04)	0.20 (0.02)
5	47	0.87 (0.05)	0.60 (0.03)	0.41 (0.06)	1.01 (0.08)	0.08 (0.03)
6	39	0.42 (0.02)	0.35 (0.05)	0.40 (0.04)	0.77 (0.05)	0.10 (0.04)
7	56	1.10 (0.04)	0.65 (0.03)	0.59 (0.03)	1.24 (0.05)	0.14 (0.02)
8	45	0.55 (0.03)	0.48 (0.02)	0.18 (0.03)	0.67 (0.05)	0.02 (0.02)
Mean (SD)	43 (7)	0.67 (0.28)	0.48(0.12)	0.38 (0.13)	0.86 (0.21)	0.11 (0.05)

BBS: Berg balance scale, SD: standard deviation.

Figure 1. Correlations between the BBS prior to wearing an AFO and temporal-spatial parameters of gait: (A) gait speed, (B) step length of the affected side and (C) stride length.



The mean BBS score was 43 (SD 7) (ranged from 33 to 56) in our study, which approximated to the mean score of 42.12 (SD 9.05) assessed in patients with chronic stroke in recent studies [12]. In general, scores of 20 to 40 represent balance impairment and 41 to 56 represent good balance [3]. Gait speed ranged from 0.22 to 1.10 m/s. This indicated that the participants who volunteered for this study could be classified as either household (<0.4 m/s), limited community (0.4–0.8 m/s), or community (>0.8 m/s) ambulators [13]. Although the results of this study were based solely on the temporal-spatial parameters, the addition of joint kinematic and kinetic data would more completely classify and analyze the gait patterns of patients with stroke [14].

The AFOs used in our study were those previously supplied to the participants. Some studies investigating the effects of AFOs on hemiplegic gait have favored specific AFO designs in their testing regime [9]. However, recent studies have demonstrated the importance of providing an optimal sagittal plane inclination of the shank of the affected lower limb during gait using an appropriate AFO/footwear combination, as well as matching an AFO's mechanical properties to that of a patient's physical characteristics [15,16]. Therefore, the effect of alignment and stiffness of AFOs needs to be considered in future studies [17].

The BBS demonstrated significant correlations with gait speed, step length of the affected side and the stride length in patients with chronic stroke while walking with an AFO in this study. The hypothesis of the study was confirmed. Therefore, assessment of the BBS prior to AFO prescription may potentially help clinicians to estimate the gait speed with an orthotic intervention, such as an AFO in patients with hemiplegia. However, the number of the participants recruited in this study was small, and they were not very homogenious. The range of period post-stroke was between eight and 40 months. Six participants used non-articulated AFO, while two participants used articulated AFO. Therefore, the results demonstrated in this study may not represent the general population of patients with chronic stroke. A further study with a multifactorial analysis involving a larger cohort of patients with stroke is needed to confirm the results of this study.

Conclusion

The assessment of the BBS prior to AFO prescription may be potentially helpful for orthotists to estimate gait speed with the orthotic intervention in patients with stroke.

Declaration of interest

The authors declare that there is no conflict of interest.

This work was funded by the Hong Kong Polytechnic University International Postgraduate Scholarships for PhD Studies and the Research Fund of the Hyogo Prefectural Government.

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