Original Article

Concurrent and Discriminative Validity of the Mini Balance Evaluation Systems Test (miniBESTest) in People with Parkinson's Disease

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Abstract

Purpose. To examine the concurrent and discriminative validity of the miniBESTest in individuals with Parkinson's disease (PD).

Method: Thirty-four individuals with PD participated in study 1. Thirty-one healthy subjects and 127 individuals with PD completed study 2. All participants were assessed at the University Balance and motion analysis laboratory. Balance performance was assessed using the miniBESTest and Berg's balance scale (BBS). Self-perceived balance confidence level of subjects was measured by the activities-specific balance confidence (ABC) scale.

Results: In study 1, results of Pearson's correlation showed that the scores of the miniBESTest correlated well with BBS ($r=0.765$; $p<0.001$) and moderately well with ABC scores ($r=0.587$; $p<0.001$). For study 2, results of one-way analysis of variance demonstrated significant differences in miniBESTest scores among healthy subjects, PD non-fallers (PD-NF) and PD fallers (PD-F). Healthy subjects obtained the highest mini-BESTest score of 88.2 ± 8.9%, followed by PD-NF (73.6 ± 14.7%) and PDF (57.1 ± 17.0%) (all $p<0.001$). Significant differences were also observed among healthy subjects, PD-NF and PD-F for each miniBESTest domain score (all $p<0.05$).

Conclusion: The miniBESTest is a valid method to document balance performance in individuals with PD. Both total and domain miniBESTest scores could differentiate between healthy subjects, PD-NF and PD-F.

Key words: **Accidental falls, measure, balance, stability, Parkinson's disease.**

Introduction:

Falls are a serious problem in people with Parkinson's disease (PD). In a 20-year prospective follow-up study[1], it was reported that 87% of individuals with PD had one or more falls and 35% sustained a fracture as a result of falling. Falls lead to devastating consequences such as restriction of mobility, physical deterioration and early institutionalisation[2]. Evaluation of balance and mobility is important to determine the risk of falling for individuals with PD and the efficacy of treatment in this patient population. Berg's balance scale (BBS), a multi-factorial measure of functional balance ability, is commonly used to assess balance performance[3], and has been found to be reliable and valid for use in individuals with PD[4]. It tests a person's balance ability during sitting, standing, transfer, and stepping activities, and is relatively safe and easy to administer. However, the emphasis of BBS is on functional performance and disregards important aspects of dynamic balance control such as the ability to respond to external perturbation, the ability to maintain balance following different sensory inputs, and stability during walking activities.

A new clinical tool called the balance evaluation systems test (BESTest) has been reported[5]. It is a comprehensive assessment tool that aims to identify impaired balance systems that underlie poor functional balance ability and to focus on specific training strategies. It comprises 36 items that are classified into six domains, i.e., biomechanical constraints, stability limits/verticality, sensory organization, anticipatory postural adjustments, postural responses, and dynamic balance during gait. This

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comprehensive test was found to be reliable and valid in assessing balance performance in 22 subjects with or without balance disorders[5]. However, it takes about 40 min to administer, which reduces its application in clinical use. In response to this limitation, Franchignoni *et al*[6] simplified the BESTest to a miniBESTest which can be completed within 15 minutes. Twenty-four items which were found to represent a uni-dimensional construct of dynamic balance were selected from the BESTest by factor analysis. Rasch analysis was used to delete a further 10 items which showed a misfit or high local dependency. The remaining 14 items comprise four domains, sensory organisation, anticipatory postural adjustments, postural responses, and dynamic balance during gait. The miniBESTest was validated in a convenience sample of patients with balance disorders resulting from various neurological conditions including hemiparesis, PD, neuromuscular diseases, ataxia, multiple sclerosis and traumatic brain injury[6]. For the miniBESTest to be used in the evaluation of individuals with PD, it was essential to examine its validity in this patient group. In addition, it was crucial to examine whether it could distinguish between healthy subjects, PD fallers (PD-F) and PD non-fallers (PD-NF).

The present study consisted of two inter-related studies. Study 1 aimed to examine the concurrent validity of the miniBESTest by hypothesising that it would correlate with BBS, a well established balance performance test, and the subjective activity-specific balance confidence scale (ABC). Study 2 aimed to explore the discriminative validity of the miniBESTest by hypothesising that the scores of miniBESTest could distinguish between healthy subjects, PD-NF, and PD-F.

Materials and Methods:

Subjects:

Studies 1 and 2 were cross-sectional comparative studies on two groups of individuals with PD and healthy older adults. Individuals with PD were recruited from the Hong Kong PD Association, a patient self-help group, and healthy subjects were recruited from local health centres for the aged. All participants joined the studies on a volunteer basis. Individuals with PD had to be aged 40 years or above, to be diagnosed with idiopathic PD by neurologists[7], to be on levodopa treatment, to be able to stand independently and walk with or without an assistive device for a distance of 6m and for a duration of 1 minute, and to have cognitive function adequate for participation in the study, with a mini mental status examination score of 23 or above[8]. Individuals with neurologic conditions other than PD, cardiovascular, orthopaedic or vestibular impairment that would limit their balance or the ability to initiate gait, visual and hearing problems, or the presence of severe on/off L-dopa motor fluctuations or dyskinesia were excluded from this study. The inclusion and exclusion criteria of healthy subjects were similar to those of the patient group except that they did not have PD. Ethical approval was obtained from the University Ethics Committee. All participants gave informed consent according to the declaration of Helsinki prior to data collection.

Procedures:

All tests were carried out at the Balance and Motion Analysis Laboratory of the Hong Kong Polytechnic University. All individuals with PD were tested once during the on-phase of anti-parkinsonian medication, i.e., within 1-2 hours after taking their medications. The assessment was performed by a physiotherapist who was blinded to the research questions. Demographic data, duration of PD since diagnosis, time since last anti-PD medication prior to the examination, and history of falls were collected. Fallers were defined as subjects having had two or more falls in the previous 12 months[9]. The Hoehn and Yahr (HY) scale was used to quantify the severity level of PD[10], and ranged from stage 0 to 5, where the higher value indicates more severe PD. The Unified Parkinson disease rating scale-motor examination (UPDRS-III) scores were used to measure the level of impairment and disability in individuals with PD[11]. The UPDRS-III comprises 14 items with 27 distinct functions that document speech, facial expression, tremor, rigidity, agility, posture, bradykinesia, and postural and functional activities. Each item is scored from 0 to 4, where a higher score implies greater impairment of motor function. The total UPDRS-III score ranges from 0 to 108.

The BBS comprises 14 items that cover maintenance of static posture and balance ability during standing. Each item is scored on a four-level ordinal scale from 0 (worst performance) to 4 (best performance), with a total score of 0-56. The test-retest reliability of BBS was reported to be excellent (ICC=0.97)[12]. The miniBEST test comprises 14 items that cover four domains of balance and mobility tasks: anticipatory postural adjustment, response to perturbation, sensory orientation, and dynamic stability in gait with or without a concurrent task. Each item is scored from on a three-level ordinal scale from 0 (worst performance) to 2 (best performance). Total miniBESTest scores and scores under each domain are presented as a percentage of the total score range from

0 to 100[6]. The miniBESTest was found to have good test-retest reliability (ICC=0.86)[6]. Both the BBS and the miniBESTest can be completed within 15 minutes. The validated Chinese version of the ABC scale was used to provide an estimate of fear of falling[13], and was shown to have excellent test-retest (ICC=0.99) and good inter-test reliability (ICC=0.85)[13]. Subjects were asked to rate their self-perceived level of balance confidence from 0 (no confidence at all) to 100 (full confidence) for completing 16 activities of daily living. The mean score of the 16 activities was calculated, ranging from 0 to 100; a low ABC score reflected greater fear of falling.

Statistical analysis:

All data were analysed using SPSS version 17 (SPSS Inc., Chicago, USA). The normality of all continuous data was checked using the Kolomogorov-Smirnov test. For study 1, parametric Pearson's r or non-parametric Spearman's rho was used to evaluate the correlation between the miniBESTest and BBS, and between the miniBESTest and ABC, depending on the normality of the data. For study 2, if data were normally distributed, differences between healthy subjects, PD-NF and PD-F for demographics, miniBESTest scores and miniBESTest domain scores were analysed by one-way analysis of variance (ANOVA) with post-hoc Tukey tests. Gender of the subjects (nominal data) was tested using the Chi-square test. Ordinal data and data that did not meet the criterion of normality were analysed using Kruskal-Wallis and Mann-Whitney U tests with bonferroni correction for post-hoc tests. The level of significance was 0.05.

Results:

Study 1: Thirty-four individuals (20 men and 14 women) with PD completed the study. The mean age of the participants was 63.1±9.3 years, and their mean body weight and height were 58.7±9.4 kg and 160.6±8.1 cm, respectively. The individuals had PD for 7.6±5.3 years, had HY stages of 2.1±0.7, and UPDRS-III of 20.4±8.3, indicating mild to moderate levels of disease severity and motor impairment. They had a mean BBS score of 51.9±5.2, miniBESTest score of 70.6±17.5%, and ABC score of 76.6±20.4. Results of Pearson's correlation showed that the miniBESTest scores correlate well with BBS ($r=0.765$; $p<0.001$) and moderately well with ABC ($r=0.587$; $p<0.001$)[14].

Study 2: After the completion of study 1, we invited all participants to join study 2, and 20 of them agreed to join the study. Thirty-one healthy subjects and 127 individuals with PD completed study 2. Table 1 shows no significant difference in subject characteristics among healthy subjects, PD-NF and PD-F. It also shows that PD-F had a significantly longer duration of PD ($p=0.01$), a significantly higher HY score ($p<0.001$) and a higher UPDRS-III score ($p=0.001$) compared with PD-NF, indicating that PD-F had more severe PD and greater motor impairment than PD-NF. Results of one-way ANOVA demonstrated significant differences among healthy subjects, PD-NF and PD-F for miniBESTest scores (Table 2). Healthy subjects obtained the highest mini-BESTest score of 88.2 ± 8.9%, followed by PD-NF (73.6±14.7%) and PD-F (57.1±17.0%) (all $p<0.001$). Results also showed significant differences among the three subject groups for all miniBESTest domains (all $p<0.05$; Table 2).

Discussion:

The study generated two new findings. First, the miniBESTest is a valid measure of balance performance in individuals with PD as its scores correlated well with those of BBS and ABC. Second, the miniBESTest has good discriminative validity as both its total and domain scores were able to distinguish between healthy subjects, PD-NF and PD-F.

Table 1: *Subject Characteristics*

Demographics	C (n=31)	PD-NF (n=94)	PD-F (n=33)	P-value		
				C *versus* PD-NF	C *versus* PD-F	PD-NF *versus* PD-F
Age (years)	62.6±9.3	62.1±9.9	65.2±7.4		0.258	
Weight (kg)	58.7±10.9	59.0±9.9	59.1±10.9		0.983	
Height (cm)	157.1±8.5	160.9±7.9	160.4±7.3		0.063	
Gender (Female)	17	38	16	0.161	0.611	0.420
MMSE score (0-30)	28.3±2.1	28.0±2.6	27.5±2.8		0.432	
PD duration (years)	—	6.4±4.9	9.6±6.2	—	—	0.010*
HY score (0-5)	—	2.3±0.6	2.7±0.6	—	—	<0.001*
UPDRS-III score (0-108)	—	25.2±11.0	32.7±9.9	—	—	0.001*

* P <0.05; C: Control subjects; PD-NF: Parkinsonian non-fallers; PD-F: Parkinsonian fallers; MMSE: Mini-mental state examination; HY: Hoehn and Yahr staging; UPDRS: Unified Parkinson's disease rating scale

Table 2: *Comparisons of the Total and Domain Scores of MiniBESTest Among Healthy Subjects, PD Non-fallers and PD Fallers*

Variables	C (n=31)	PD-NF (n=94)	PD-F (n=33)	P-value		
				C *versus* PD-NF	C *versus* PD-F	PD-NF *versus* PD-F
Mini-BEST score (0-28)	24.7±2.5	20.6±4.1	16.0±4.8	<0.001*	<0.001*	<0.001*
Mini-BEST score (0-100%)	88.2±8.9	73.6±14.7	57.1±17.0	<0.001*	<0.001*	<0.001*
Anticipatory transitions (0-100%)	93.0±10.3	78.5±17.7	62.6±22.4	<0.001*	<0.001*	<0.001*
Postural responses (0-100%)	81.7±22.1	57.4±33.5	27.3±26.3	<0.001*	<0.001*	<0.001*
Sensory orientation (0-100%)	95.7±9.6	84.0±19.7	69.2±23.2	0.010*	<0.001*	<0.001*
Dynamic gait (0-100%)	84.8±13.1	74.1±13.5	64.5±18.9	0.002*	<0.001*	0.004*

* P <0.05; C: Control subjects; PD-NF: Parkinsonian non-fallers; PD-F: Parkinsonian fallers; Mini-BEST: Mini Balance Evaluation System Test

Concurrent validity: BBS is the gold standard tool for clinical balance assessment for people with balance disorders. Its use in individuals with PD has also been validated[4]. Leddy *et al*[15] reported that the BESTest score had high correlation with BBS score (r=0.873). We found that there was good correlation between simplified miniBESTest and BBS scores (r=0.765)[14]. The satisfactory concurrent validity with BBS suggests that the miniBESTest is a valid test of balance performance in individuals with PD. Apart from three items (sit-to-stand, single-leg stance, and standing with feet together) that are similar in both the miniBESTest and BBS, BBS focuses on measuring balance performance during standing while the miniBESTest assesses balance during both standing and walking activities. The miniBESTest comprises five items that challenge subjects' balance during walking at changing speeds, walking with the head turned, walking with pivot turns, stepping over obstacles, and walking while performing a concurrent task. Since most fall-related activities occur during walking in individuals with PD[16-18], the miniBESTest could be more specific for assessing their balance performance. In addition, the miniBESTest assesses compensatory stepping responses whereas BBS does not include any test on postural responses. A poor and inflexible postural response to external perturbations such as slow and small amplitude of step responses has been reported to relate to balance deficits in individuals with PD[19-21]. Among the available clinical tests, the retropulsion test was found to be the most valid for postural instability in individuals with PD[22], and is included in the UPDRS to assess postural instability. The inclusion of this domain shows that the miniBESTest is specific to address balance performance in individuals with PD. In the present study, the mean BBS score of the participants was 51.9 (out of 56) and the mean miniBESTest score was 70.6% (out of 100%), which indicates that BBS could potentially show a ceiling effect in the evaluation of balance performance in individuals with PD[23,24].

In this study, a moderate correlation was found between miniBESTest and ABC scores in individuals with PD, which was consistent with a positive correlation between BESTest and ABC scores in a group of patients with various neurological disorders[5]. Our findings confirmed that poor balance performance in the miniBESTest was associated with a reduced level of self-perceived confidence or greater fear of falling. The latter was found to be associated with falls and was a significant predictor of future falls in people with PD[25,26]. This further supports the validity of the miniBESTest to measure balance deficits in individuals with PD who had mild to moderate disability.

Discriminative validity: Horak *et al*[5] reported that healthy subjects had significantly higher BESTest scores than individuals with PD. We confirmed these results and also found that PD-NF had significantly higher scores than PD-F. The sensitivity of the miniBEST test to discriminate between these three groups of subjects supports the second hypothesis that the miniBESTest has good discriminative validity. In the present study, fallers were defined as individuals who had at least two falls in the previous 12 months because recurrent falls are more likely to have a disabling impact on an individual's life[27]. The lower miniBESTest score attained by both PD-NF and PD-F in comparison with healthy subjects implied that they had poorer dynamic balance ability and explained their higher risk of falling.

When the four domains of the miniBESTest were examined, we further found that individuals with PD had poorer performance than control subjects in every domain, and that significant differences existed between PD-NF and PD-F. Among the four domains, PD-F had exceptionally low scores in 'postural response'. The

commonly perceived causes of falls in individuals with PD were tripping and slipping[18]. However, individuals with PD demonstrated longer latencies, shorter steps and slower step velocity for postural correction in both lateral[28] and anterior-posterior directions[29]. Individuals with PD also had difficulty in selecting appropriate postural response strategies to regain balance and in altering their response with a change in the direction of the perturbation[30]. A poor postural response would increase the risk of falling. Anticipatory postural adjustments are made by postural muscles that are activated in a feed-forward manner prior to an expected perturbation[31]. People with PD have been shown to exhibit anticipatory postural adjustment with prolonged duration and reduced amplitude[32,33]. A low score in the domain 'anticipatory postural adjustments' could increase the risk of falling during transfer and sit-to-stand[16,18].

PD-F had poorer scores than PD-NF in the domain 'sensory orientation' especially under conditions of standing on foam and an inclined stance. Individuals with PD were found to have impaired proprioceptive integration and rely more heavily on visual feedback when their equilibrium was challenged[29,34]. Under blindfold conditions, individuals with PD and especially PD-F might have difficulty to use proprioceptive sensation to maintain their balance. Dynamic gait stability challenges subjects with regard to walking at different speeds, with pivot turns and while performing concurrent motor tasks (i.e., head turning, stepping over obstacles) and concurrent cognitive tasks of counting backwards. Walking and turning are the most common activities that cause falls[16-18]. People with PD were found to be unable to modulate their gait speed and walk at a slow pace[35]. Turning was difficult irrespective whether the angle was small or large[17,36-38]. Dual-task walking was more difficult than walking alone[39-41] and PD-F had worse dual-task walking performance than PD-NF[42]. The low score obtained by both PD-NF and PD-F shows that this domain is specific for assessing individuals with PD. Our findings support that the domain scores of the miniBESTest are sensitive to discriminate between healthy subjects, PD-NF and PD-F.

This study has several limitations. First, we examined ambulatory, community-dwelling people with PD, as their relatively higher level of mobility would presumably expose them to a greater number of situations where they would be at risk of falling. The findings of the present study could apply to PD subjects who have no comorbidity but could not be generalized to individuals with PD at all ambulatory stages or those who live in institutions. Second, this is a cross-sectional study and a causal relationship between falls and miniBESTest scores could not be established. Future studies should examine the use of the miniBESTest to assess balance performance in a larger sample of patients at all stages of the disease, and with different levels of mobility. Further prospective study is needed to examine the ability of the miniBESTest to predict future falls and to determine a cut-off score for the prediction of falls in people with PD.

To conclude, the study established the concurrent and discriminative validity of miniBESTest in individuals with PD. The miniBESTest should be a useful measurement tool to quantify the balance deficits in PD populations.

Clinical messages:

- MiniBESTest is found to be a valid measure of balance performance in individuals with Parkinson's disease.
- Both total and domain miniBEST score discriminate between healthy subjects, Parkinsonian non-fallers and Parkinsonian fallers

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