Are Measures Employed in the Assessment of Balance Useful for Detecting Differences among Groups that Vary by Age and Disease State?

Sandra S. Brotherton, PT, PhD;[1] Harriet G. Williams, PhD;[2] Joyce L. Gossard, MS;[2] James R. Hussey, PhD;[3] Bruce A. McClenaghan, PT, PED;[2] Paul Eleazer, MD[4]

[1]Physical Therapy Educational Program, Department of Rehabilitation Sciences, Medical University of South Carolina, Charleston, SC
[2]Department of Exercise Science, Arnold School of Public Health, University of South Carolina, Columbia, SC
[3]Department of Epidemiology and Biostatics, Arnold School of Public Health, University of South Carolina, Columbia, SC
[4]School of Medicine, University of South Carolina, Columbia, SC

ABSTRACT

Purpose: This study explored the usefulness of measures commonly employed in the examination of persons with balance impairment to discriminate between performances of young and older adults and older adults with and without neurological disease. **Methods:** Eighteen young adults, 22 healthy older adults, 12 individuals with Parkinson disease, and 20 older adults with peripheral neuropathy were recruited from the community. Performances on the following measures were compared: Mini Mental State Exam, grip strength, timed chair rise, semitandem and tandem stance, Timed Up and Go (TUG), and Berg Balance Scale (BBS). Survival analysis was used to analyze semitandem and tandem stance. Grip strength and other tests were analyzed using analysis of variance. Tukey multiple comparison procedure was employed to assess differences in performance among groups. **Results:** Significant differences in performance were found for all measures. Grip and timed chair rise discriminated young and older adult groups. Timed chair rise, tandem stance, TUG, and BBS detected differences between healthy individuals and those with disease. Semitandem stance and BBS discriminated between individuals with disease conditions. **Conclusions:** When examining individuals with balance difficulty, combinations of measures are needed to discriminate between clinically distinct groups.

Key Words: strength, balance, aging, neuropathy, Parkinson disease

INTRODUCTION

Numerous investigators have attempted to identify intrinsic factors that contribute to balance impairment in community dwelling older adults.[1-6] Sedative use, cognitive decline, lower extremity disability, and balance and gait disturbances have been found consistently to be predictors of falls.[1] Other evidence suggests that decreased grip strength,[3] impaired sensation of distal lower extremities, and decreased ankle strength also are important discriminating risk factors.[6] Risk for falling increases with difficulty in standing up from a chair, inability to perform a tandem walk, presence of arthritis or Parkinson disease, and history of recurrent and injurious falls.[2]

Address correspondence to: Sandra S. Brotherton, PT, PhD, Physical Therapy Education Program, Department of Rehabilitation Sciences, Medical University of South Carolina, PO Box 250700, Charleston, SC 29425 Ph: 843-792-2930, Fax: 843-792-0710 (brothers@musc.edu).

Declines in neuromuscular and sensory systems contribute to loss of balance and may be associated with aging[7-10] or the presence of disease.[11-18] Research has shown that healthy older adults[7,9,10] and those with neurological diseases such as Parkinson disease[12,13,15] experience delays in muscle activation, demonstrate a decrease in the magnitude of muscle response, and have difficulty with activation of muscles in the appropriate sequence in response to balance disturbance. Healthy older adults[8,10] and individuals with disease, particularly those with peripheral neuropathy,[14] exhibit increased postural sway and may become unstable and lose balance when exposed to altered visual and somatosensory inputs during quiet stance.

Because many factors contribute to instability, a variety of measures have been incorporated into the examination of individuals with balance problems. The Mini Mental State Examination,[19] a screening tool for cognitive impairment, is often used because of the association between cognitive decline and increased risk for falls. Grip strength, an indicator of overall strength,[3] and timed chair rise,[20] a more specific screening measure of lower extremity muscle force, have been used to assess the contribution of strength to balance difficulty. Static balance performance has been assessed using semitandem and tandem stances,[21] while dynamic balance and functional ability have been evaluated with the Timed Up and Go (TUG)[22] and Berg Balance Scale (BBS).[23]

Identification of measures that can detect performance differences among individuals can assist clinicians in selecting appropriate tests to include in the examination of persons with balance impairment and facilitate development of interventions to reduce impairments. Thus, the purpose of this study was to determine if tests employed in balance assessment were useful for detecting differences among groups that varied by age and disease state. To accomplish this goal, we compared performances of healthy young and older adults and individuals with central (Parkinson disease) and peripheral (peripheral neuropathy) nervous system disorders on measures commonly used in examination of individuals with balance impairment.

METHODS

Subjects

Eighteen healthy young adults, 22 healthy older adults, 12 individuals with Parkinson disease, and 20 older adults with peripheral neuropathy participated in the investigation. Young adults were recruited from students enrolled at the University of South Carolina in Columbia, South Carolina. Older adults were identified through community support groups, local physicians, and advertisements at senior centers. The Institutional Review Board at the University of South Carolina approved the study, and all subjects provided informed consent.

All participants were medically stable community-dwellers, who could stand for 15 minutes, walk 30 feet without assistance, and follow simple instructions. Individuals were excluded if they reported impaired balance due to recent medication change or exhibited orthostatic hypotension as evidenced by a decrease in systolic blood pressure of 30 mmHg or more after a change in position from supine to standing.[24] Healthy subjects were free from conditions known to affect balance such as stroke with residual lower limb weakness or sensory loss, cardiac conditions that would limit participation, Parkinson disease, peripheral neuropathy, and lower extremity joint replacement and amputation. Individuals with Parkinson disease and peripheral neuropathy were free of other conditions known to affect postural control.

Healthy young and older adults could have no more than a single fall over the previous 12 months. For this study, a fall was defined as an unplanned, unexpected contact with the supporting surface[25] that was associated with intrinsic factors. Events caused by extrinsic factors, such as unavoidable environmental hazards, were not categorized as falls.

All individuals with Parkinson disease were referred by a physician and were classified as Stage II or III using the Hoehn and Yahr scale.[26] Stage II is characterized by bilateral symptoms, minimal disability, and involvement of posture and gait. Stage III is distinguished by significant slowing of body movements, early impairment of equilibrium in walking and standing, and moderately severe generalized dysfunction. Parkinson disease patients were maintained on their usual medication and tested during the 'on' phase of the medication cycle.

Most subjects in the peripheral neuropathy group (16 of 20) had been diagnosed with the condition by a physician and were taking medication to relieve pain associated with neuropathy. Four additional subjects were placed in this group based on a combination of clinical signs and symptoms that included complaints of paresthesia in the feet, loss of protective sensation on the plantar surface of the feet, claw toe deformity secondary to intrinsic muscle weakness in the feet, and presence of dry, cracked skin on the feet associated with autonomic neuropathy.[27]

Procedures

Demographic and health questionnaires, screening for orthostatic hypotension and peripheral neuropathy, and clinical measures were administered during a single testing session of 1.5 hours. Questionnaires and screening tests were completed first because the information obtained was used to determine presence of exclusion criteria and to characterize groups. Clinical measures of mental and physical condition, static balance, and functional performance were then carried out, beginning with simple tests and progressing to multistep tests. This order was used for all subjects as it allowed them to gain confidence and become acclimated to the testing environment. All tests were administered by a physical therapist with 25 years of experience and a trained assistant.

Demographic and health information was collected during an interview in which the investigator read the questions to each participant and recorded responses. Demographic data included age, gender, race, and marital status. Health information included past and current medical problems, medications, and the number of falls over the previous 12 months.

Screening for orthostatic hypotension and peripheral neuropathy was performed after the interview. Blood pressure was measured in the left arm in supine and standing positions to determine if the systolic pressure decreased by 30mmHg or more in response to position change, an indication of orthostatic hypotension. Individuals were then screened for peripheral neuropathy using subjective report of paresthesia, observation for claw toe deformity and tropic skin changes, and testing for protective sensation at multiple sites on the plantar surface of each foot using the Semmes-Weinstein monofilament.[27] Inability to perceive 10 g of pressure supplied by the 5.07 monofilament indicated loss of protective sensation.[27]

Clinical measures administered to the subjects included the Mini Mental State Examination, grip strength, timed chair rise, semitandem and tandem stances, TUG, and BBS. A description of the tests, test scoring, and validity and reliability are presented in Table 1.

Data Analysis

Means and standard deviations were calculated for age, and frequency distributions were obtained for all other demographic and health data. A generalized linear model was used to perform Poisson regression for self-reported health variables, and contrasts were used to examine differences among groups. A Bonferroni correction was applied to contrast results since multiple comparisons were made.

Means and standard deviations were calculated also for all clinical measures. One-way analysis of variance (ANOVA) was used to analyze between- group differences in Mini Mental State Examination scores, timed chair rise, TUG, and BBS scores. A 2-way ANOVA was used to analyze grip strength to look for differences among groups while adjusting for gender. Tukey post hoc multiple comparison procedures were used to identify significant differences among groups. Survival analysis was used to compare semitandem and tandem stance times among groups since both measures had predetermined fixed endpoints (30 sec). Significance level was set at $P < 0.05$ for all statistical procedures. All analyses were performed using SAS software, version 8.0.[36]

RESULTS

Demographic and self-reported health data are summarized in Table 2. The Parkinson disease group was older and

Table 1. Information on Clinical Measures Employed

Description	Score	Validity	Reliability
Mini Mental State Examination 11 questions divided into 2 parts.[19]	Maximum score = 30	Concurrent validity established with Wechsler: Pearson r = 0.776 (verbal); Pearson r = 0.660 (performance).[19]	Reported index of association using Pearson coefficient of correlation: intrarater consistency = 0.887; interrater consistency = 0.827.[19]
Grip Strength Jamar dynamometer held in preferred hand, arm raised overhead then slowly lowered toward floor; squeezed as hard as possible.[28]	Pounds of force; average of 3 trials.		0.82[29]
Timed Chair Rise Seated in a straight-back chair, subject, on cue, moved to full stand and sat down as quickly as possible. Performed barefooted; upper extremity use not permitted.[20]	Time to complete 10 stands to nearest 0.1 second.	Concurrent validity established by comparing with lower body strength (Pearson r = 0.71-0.78).[30] Construct validity established; detects differences between age groups.[30]	Test-retest reliability of older adults, average age 70: ICC = 0.84-0.92;[31] for frail older adults: ICC = 0.67.[32]
Semitandem and Tandem Stances Subjects stood barefooted in semitandem and tandem positions up to a maximum of 30 seconds.[21]	Time to the nearest 0.1 second; average time for 3 trials.	Concurrent validity established by comparing with mobility measures.[33]	Reported index of association using Pearson coefficient of correlation: test-retest consistency = 0.25-0.74.[34]
Timed Up and Go Subjects sat in a chair, stood up without using the hands, walked to the end of a 10-foot pathway, turned around, walked back, and sat down as quickly and safely as possible.[22]	Time to the nearest 0.1 second; 1 practice, average time for 2 trials.	Concurrent validity established by comparing with BBS (Pearson r = -0.81), gait speed (Pearson r = -0.61), and Barthel Index (Pearson r = -0.51).[22]	Interrater reliability: ICC = 0.99; intrarater reliability: ICC = 0.99.[22]
Berg Balance Scale 14 movements common in everyday life.[23]	Each item rated 0 (unable to perform) to 4 (normal performance); maximum score is 56.	Concurrent validity determined by comparison with postural sway (Pearson r = -0.55), Performance-Oriented Mobility Assessment balance subscale (Pearson r = 0.91), and TUG (Pearson r = 0.76).[35]	Internally consistent: Cronbach's alpha 0.96. Interrater reliability: ICC = 0.98; intrarater reliability: ICC = 0.99.[23]

had more males. Most participants in all groups were Caucasian, and more older adults were married. The number of comorbidities (F = 58.9, P < 0.0001), prescription medications (F = 109.9, P < 0.0001), and falls (F = 39.5, P < 0.0001) differed among groups. Young adults had significantly fewer comorbidities and took fewer medications than all older adults. Healthy older adults also took fewer medications than Parkinson disease patients. Individuals with Parkinson disease and peripheral neuropathy had significantly more falls than young adults, and those with peripheral neuropathy had more falls than healthy older adults.

Descriptive statistics for clinical measures are presented in Table 3. Significant differences among groups were found for Mini Mental State Examination scores (F = 4.54, P = 0.006), grip strength (F = 29.25, P < 0.0001), timed chair rise (F = 20.51, P < 0.0001), TUG (F = 18.53, P < 0.0001), and BBS scores (F = 21.79, P < 0.0001). A superscript letter placed after the mean and standard deviation is used to indicate differences between groups. Means with the same letter are not significant. For example, no differences in Mini Mental State Examination scores were found among young adults, healthy older adults, and those with peripheral neuropathy as indicated by superscript ^{a}. However, individuals with Parkinson disease differed from young adults and healthy older adults but did not differ from the peripheral neuropathy group as indicated by superscript ^{b}.

Survival analysis revealed significant differences among groups on performance of both semitandem (P = 0.0002) and tandem (P = 0.0001) stance. When semitandem stance was analyzed across all 4 groups, many subjects (90.1%) achieved the maximum balance time of 30 seconds. When healthy subjects were removed from the analysis, only 78.1% of subjects maintained balance for 30 seconds. Significant differences in semitandem stance were then found between individuals with Parkinson disease and peripheral neuropathy (P = 0.039). Parkinson disease subjects were more likely to fail to complete the task than those with peripheral neuropathy. For tandem stance, significant differences existed between healthy subjects and those with disease; subjects with disease were more likely to fail to maintain balance than healthy subjects.

DISCUSSION

Of the mental and physical condition measures, the timed chair rise had the greatest capacity to detect differences between groups. The Mini Mental State Examination detected declines in cognition experienced by Parkinson disease subjects that were likely associated with the disease process. This finding is consistent with Azuma et al,[37] who found a 4-point decline in scores with a group of Parkinson disease patients over a 2-year period. Thus, the Mini Mental State Examination

Table 2. Demographic Characteristics and Self-Reported Health Information*

Variable	Young Adults n = 18	Healthy Older Adults n = 22	Parkinson Disease n = 12	Peripheral Neuropathy n = 20
Age, mean (SD), years	22.3 (2.8)	69.9 (4.8)	76.2 (6.0)	71.8 (7.5)
Gender				
Male	5 (28)	7 (32)	7 (58)	4 (20)
Female	13 (72)	15 (68)	5 (42)	16 (80)
Race				
White	13 (72)	18 (82)	12 (100)	20 (100)
Nonwhite	5 (28)	4 (18)	0 (0)	0 (0)
Marital Status				
Unmarried	15 (83)	7 (32)	4 (33)	9 (45)
Married	3 (17)	15 (68)	8 (67)	11 (55)
Comorbidities				
0-1	17 (94)	5 (23)	0 (0)	0 (0)
2-4	1 (6)	15 (68)	9 (75)	17 (85)
5-7	0 (0)	2 (9)	3 (25)	3 (15)
Medications				
0-2	18 (100)	9 (41)	1 (8)	5 (25)
3-5	0 (0)	9 (41)	5 (42)	8 (40)
6-9	0 (0)	3 (14)	4 (33)	5 (25)
10-13	0 (0)	1 (4)	2 (17)	2 (10)
Falls				
0-1	18 (100)	22 (100)	8 (67)	15 (75)
2-6	0 (0)	0 (0)	4 (33)	4 (20)
7-12	0 (0)	0 (0)	0	1 (5)

*Values are number (percentage) unless otherwise indicated

Table 3. Performance on Clinical Measures*

Clinical Measures	Young Adults n = 18	Healthy Older Adults n = 22	Parkinson Disease n = 12	Peripheral Neuropathy n = 20
Mini Mental State Examination	28.8 (1.0) *a*	28.9 (1.2) *a*	26.7 (3.6) *b*	28.3 (1.4) *ab*
Grip Strength (pounds)†	83.3 (25.2) *a*	63.9 (20.2) *b*	62.4 (15.2) *b*	56.6 (17.8) *b*
Timed Chair Rise (sec)	15.4 (3.3) *a*	24.6 (6.2) *b*	36.2 (14.9) *c*	37.5 (12.4) *c*
Semitandem (sec)	30 (0)	30 (0)	25.9 (7.9) *a*	29.3 (2.3) *b*
Tandem (sec)	29.8 (0.7) *a*	27.8 (5.1) *b*	16.3 (12.1) *b*	15.4 (11.2) *b*
Timed Up and Go (sec)	5.5 (0.5) *a*	8.1 (1.7) *a*	14.5 (6.7) *b*	11.6 (4.3) *b*
Berg Balance Scale	55.9 (0.2) *a*	54.9 (1.4) *a*	48.8 (5.2) *b*	52.3 (2.6) *c*

*Values are mean (SD)
† Adjusted for gender
abc Means with the same letter are not significantly different

may be worthwhile to include when evaluating individuals with instability to detect cognitive declines that may be accompanied by balance impairments. Grip strength discriminated between young adults and all older adult groups suggesting that it may detect age-related changes in strength as a factor in balance assessment. Performances on the timed chair rise differentiated young adults from healthy older adults and healthy older adults from those with disease. Differences between young adults and healthy older adults are in agreement with Csuka et al.[38] Although this task has not been used to discriminate between healthy older adults and those with Parkinson disease and peripheral neuropathy, investigators have shown that performance on the timed chair rise differentiates healthy elderly from those with peripheral arterial disease and lumbar spinal stenosis.[39-41] Our data suggest that timed chair rise performance may be valuable for detecting changes associated with either age or disease.

Semitandem stance detected differences between disease groups, while tandem stance discriminated between healthy individuals and those with disease. As in previous studies,[34] ceiling effects were noted for semitandem stance performance for healthy adults; thus, it was not a meaningful measure of static balance for healthy individuals. However, significant differences were found among groups with disease, which suggests that semitandem stance may identify balance declines associated with disease conditions.

In our study, tandem stance discriminated between healthy adults and individuals with disease. Our results differ from those of some investigators, who reported a significant age difference in tandem stance performance between young and older healthy women,[42] but are supported by Stansberry et al,[43] who found that tandem stance did not differentiate between young and older adults. Tandem stance performances in our study are consistent with outcomes of other studies that compared healthy individuals and those with disease.[43,44] Stansberry et al[43] found that performances of individuals with diabetic peripheral neuropathy were significantly poorer than all other groups, and Smithson et al[44] reported significant differences between healthy individuals and those with Parkinson disease on a variety of balance tasks including tandem stance.

As with tandem stance, performances on TUG also differentiated between healthy adults and those with disease but did not differentiate among healthy individuals or disease groups. Steffen at al[45] found a trend of age-related declines for healthy individuals, age 61 to 89, when TUG scores were analyzed by 10-year age cohorts. However, we noted no differences in TUG performances among young and older adult groups. In our study, the higher TUG scores found for individuals with disease are consistent with previous studies in which higher TUG scores were recorded for individuals with Parkinson disease than for age-matched healthy adults.[46] Likewise, Hanks'[47] data on TUG show significant differences between healthy individuals and those with peripheral neuropathy.

In our study, BBS scores distinguished healthy adults from those with disease and discriminated between individuals with Parkinson disease and peripheral neuropathy. Our results are similar to those of Shumway-Cook et al[48] in that BBS discriminated between individuals with disease, who had more falls, and healthy individuals, who had fewer falls. Although Steffen et al[45] also noted a decline in BBS scores with increased age, no age-related differences in scores were found in our study when healthy young and older adults were compared.

There were several limitations associated with the study. Participants were volunteers and may not represent the population of healthy adults and individuals with Parkinson disease and peripheral neuropathy. Overall, there were more women than men in this study, and most subjects were Caucasian. Older adults, who agree to serve as volunteers, may also be healthier and better educated. Information about health and medications was collected by self-report and was dependent on accurate recall by the subjects. Both the subjects and investigator were aware of group assignment; however, the purpose of the study made blinding impractical. Subjects with peripheral neuropathy were assigned to that group based on physician diagnosis and/or clinical findings. Nerve conduction velocity studies were not performed to objectively verify the presence or absence of peripheral neuropathy; thus, it is possible that the group was not homogeneous. Lastly, findings apply only to the measures sampled and may not be extrapolated to similar clinical measures.

CONCLUSIONS

The capacity of measures employed in assessment of balance to detect differences among groups that vary by age and disease state is summarized in Table 4. These data may assist the clinician in selecting the most appropriate measures to include in the examination of the client with balance impairment.

Table 4. Measures Found to Detect Group Differences

Young and Older Adults	Healthy Adults and Individuals with Disease	Disease Groups
Grip strength	Timed chair rise	Semitandem stance
Timed chair rise	Tandem stance	Berg Balance Scale
	Timed Up and Go	
	Berg Balance Scale	

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