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Test-Retest Reliability and Construct Validity of the Tinetti Performance-Oriented Mobility Assessment in People With Stroke

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Background and Purpose: The Tinetti Performance-Oriented Mobility Assessment (POMA) is commonly used to measure balance ability in older adults. The purpose of this study was to determine the test-retest reliability and minimal detectable change (MDC) of the POMA and explore its cross-sectional and longitudinal construct validity for use in people early after stroke.
Methods: Participants were recruited if they had a first documented stroke and were receiving physical therapy during inpatient rehabilitation. The POMA, gait speed, and motor Functional Independence Measure (FIM) scores were collected at admission and at discharge from inpatient rehabilitation. A second trial of the POMA was conducted 1 day after the first trial for reliability analysis. Correlations (Spearman ρ) between raw scores of admission and discharge outcome measures, as well as change in scores between admission and discharge, were used to explore the construct validity of the POMA.
Results: Fifty-five people, with average age of 75 $\pm$ 11 years, who had experienced first documented stroke participated in the study and began inpatient physical therapy at a mean of 8 $\pm$ 5 days poststroke. Test-retest reliability intraclass correlation coefficient ($ICC_{2,1}$) was 0.84 and MDC was 6 points. The POMA scores were moderately correlated to motor FIM and gait speed scores at admission ($r_s = 0.55$ and 0.70) and discharge ($r_s = 0.55$ and 0.82.) Change scores of all 3 measures had a fair correlation ($r_s = 0.28\text{-}0.51$).
Discussion and Conclusions: Test-retest reliability and MDC of the POMA in people with stroke is similar to previous research in older adult long-term care residents. Results support cross-sectional and longitudinal construct validity of the POMA in persons early after stroke and demonstrate validity and reliability to measure balance ability in this population.
Video Abstract available (see Video, Supplemental Digital Content 1, http://links.lww.com/JNPT/A39) for more insights from the authors.

Key words: *balance, minimal detectable change, outcome measures*

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BACKGROUND AND PURPOSE

Balance dysfunction is common after stroke. It has been reported that 84% of people have some degree of balance disability 2 to 4 weeks poststroke.[1] People with stroke have increased postural sway during quiet stance and lower scores on clinical balance measures than nondisabled controls.[2] Balance disability, specifically postural sway and asymmetry in stance phase of gait, has been associated with lower scores on measures of activities of daily living for people with stroke.[3] Michael et al[4] reported a high incidence of balance-related inactivity in people following stroke that may lead to deconditioning. Difficulty with balance also contributes to the inability to walk long distances, especially in those who have slow walking speed after stroke.[5]

Loss of balance control can have a profound effect on physical functioning in people who have experienced stroke. Reactive balance is the ability to maintain postural control during an external disturbance such as a trip, a slip, or a push.[6] An example of such a disturbance is being nudged while walking in a crowded shopping mall. Postural strategies are used to maintain upright balance in these situations. Examples include static reactions such as ankle or hip strategies and dynamic reactions such as stepping or grabbing strategies.[7] Following stroke, static reactions are often impaired because of delayed reaction time, abnormal muscle co-contraction, and/or insufficient muscle force production in the paretic limb.[8,9] These deficits can lead to greater reliance on dynamic reaction strategies such as stepping. Older adults have difficulty regulating stepping reactions in response to perturbations, which has been associated with the occurrence of falls.[10,11] A recent pilot study by Lakhani et al[12] evaluated the stepping strategies of 4 participants with stroke. Their findings indicated that despite relatively high scores on clinical balance tests (ie, average Berg Balance Scale [BBS] score of 53/56 and average

Activities-Specific Balance Confidence score of 60%), participants had abnormal stepping responses to external perturbations, including multistep responses, slowed reaction time, and decreased stepping, especially with the paretic limb.

The BBS is a commonly used, valid, and reliable clinical measure for people poststroke that measures balance ability in a variety of positions including standing, transitional movement, narrowed base of support, and while stepping but does not measure reactive balance.[13-15] The Timed Up and Go (TUG) test is also used to measure functional ability and fall risk in people after stroke.[16,17] The TUG captures the time required to perform the transitional movement from a seated to standing position, walk 3 m, turn around, walk back 3 m, and sit down in a chair. The person being tested must be able to rise from the chair unassisted. This is the disadvantage of using the TUG in people very early after stroke, because many require physical assistance from a caregiver for transitional movements. The TUG measures timed walking and addresses functions specifically related to balance during walking.

The Tinetti Performance-Oriented Mobility Assessment (POMA) is a balance tool that was originally developed for use in the institutionalized, older adult population and contains both a balance and a gait component.[18] The balance component of the test assesses the patient's ability to maintain postural control while sitting statically, while rising from a chair, during the period immediately after standing, while standing with eyes open and eyes closed, while turning 360°, and during perturbation. The gait component assesses symmetry, initiation, continuity, path, base of support, and postural sway during gait.[19]

The POMA has items such as base of support and trunk sway that are measured during gait and measures reactive balance by asking the patient to react to a perturbation, aspects of balance that are not measured by the BBS. It also evaluates step length, floor clearance, base of support, and path deviation during gait, which are not captured in the TUG. The POMA may be a more useful measure than the BBS or TUG in patients who have dynamic balance deficits during walking or have difficulty with reactive balance.

The reliability and validity of the POMA for measuring balance in older adults has been established. The POMA exhibits sound reliability in the institutionalized elderly population with interrater reliability coefficients ranging from 0.80 to 0.95 and test-retest reliability reported as 0.72 to 0.86.[20-22] The gait component of the POMA demonstrates the least reliability, which may be attributed to subjectivity in the scoring of that particular component. Faber et al[21] estimated a minimal detectable change (MDC) for the POMA of 5 points in older adults living in long-term care facilities. The POMA also exhibits construct validity with gait speed in people with Parkinson disease and with the TUG in older adults.[21,23]

There is no information regarding the reliability, MDC, or validity of the POMA in people with stroke who were undergoing physical therapy during inpatient rehabilitation. The purpose of this research was to (1) determine the test-retest reliability, (2) estimate the MDC, and (3) explore the cross-sectional and longitudinal construct validity of the POMA in a cohort of patients with acute stroke at an inpatient rehabilitation hospital. We hypothesized that the POMA would have good test-retest reliability (reliability coefficient[24] $\geq$0.75) and moderate construct validity (correlation coefficient of 0.5-0.75)[24] in relationship to gait speed and the motor component of the Functional Independence Measure (FIM).

METHODS

Subjects

Participants were recruited if they had a first documented stroke, were receiving physical therapy during inpatient rehabilitation, and signed a written informed consent to participate in the study. The study was approved by the institutional review board of the Nova Southeastern University and the Delray Medical Center. Participants were excluded from the study if they had a history of a previous stroke, were medically unstable, were non–English speaking, or were unable to walk without assistance before the current stroke event. Demographic data, including participant age, gender, days poststroke, length of stay in rehabilitation hospital, and location of stroke, were collected. The Functional Comorbidity Index (FCI) was used to describe participants' comorbidities.[25] The FCI quantifies the number and types of comorbidities that are able to explain variance in physical functioning.[25] The FCI classifies comorbidities, using 18 diagnoses, with a score of 0 indicating no comorbidities and a score of 18 indicating the highest number of comorbidities.[25]

Outcome Measures

Outcome measures used in this study were the POMA, gait speed as measured by the 5-m Walk Test (5MWT), and the motor FIM. Data were collected by 4 physical therapists working on an inpatient rehabilitation unit of Delray Medical Center. The data collectors had an average of 13 years of experience as physical therapists at the time of data collection and had minimal prior experience administering the POMA and the 5MWT. Each of the data collectors had extensive experience administering the motor FIM. Data collectors were trained in study procedures and practiced administering the POMA and the 5-m Walk Test before the beginning of data collection. The primary physical therapist working with a participant was responsible for collecting data at both admission and discharge for that participant.

The POMA was used to measure balance ability. The test comprises 16 items (9 balance-related items and 7 gait-related items), with the highest achievable score being 28 points, 16 of which are in the balance component and 12 of which are in the gait component. The test takes approximately 10 minutes to administer.[19] The POMA allows use of assistive devices during testing. A higher score indicates better balance, and a lower score indicates poorer balance. A cutoff score of greater than 17 points has been associated with fall risk in the older adult population.[18]

Gait speed measured by the 5MWT was used to measure walking ability. Comfortable gait speed is a valid and reliable tool to measure walking ability in people with stroke.[16,26-29] The 5-m comfortable-walk test has been shown to be responsive to change in persons with stroke.[28] Previous research has shown a relationship between balance and gait speed; gait speed of less than 0.56 m/s has been associated with recurrent falls.[1,30] Studies that examine the reliability and validity of gait speed as an outcome measure in people with stroke have used it both with and without physical assistance from a caregiver.[27,31,32] It is unrealistic to exclude people who need physical assistance when conducting research in people who are within the first 3 months after stroke. Most people early after stroke need some degree of physical assistance to walk safely. Gait speed is reliable (intraclass correlation coefficient [$ICC_{2,1}$] = 0.97) with people who require assistance to walk.[27] Gait speed can be a valuable outcome measure in people early after stroke, but may be interpreted differently depending on whether or not the person needs physical assistance.[27,32]

The motor FIM was selected as the measure with which the POMA would be compared, because the motor FIM is a commonly used tool to measure activity-based function that demonstrates validity and reliability in people with stroke.[33-38] The motor FIM is used to measure functional mobility and activities of daily living in people after stroke who are undergoing inpatient rehabilitation, and initial FIM scores can be used to predict functional recovery poststroke.[39,40]

Procedures

All testing was performed in the physical therapy gym at the rehab hospital. The order of testing depended on participant tolerance to testing, but the suggested order was the 5MWT first, then the POMA, and then the motor FIM. The motor FIM data were collected from the medical chart. Motor FIM scores were gathered by rehab clinicians trained in administration of the FIM instrument. Participants were monitored by the data collectors for signs of fatigue such as shortness of breath or pain and were given rest breaks as needed between each test. Participants were required to wear gait belts and were guarded by physical therapists during all testing to ensure safety. All outcome measures including the POMA, comfortable gait speed measured by the 5MWT, and motor FIM scores were collected during the initial physical therapy examination at admission to inpatient rehabilitation and again at discharge.

The POMA measurements were taken on 2 separate occasions at admission to physical therapy. The first test was administered during the initial physical therapy examination, and the retest was conducted 1 day later to assess test-retest reliability with a minimum of practice or learning effect. The POMA was repeated again at discharge. The POMA was administered consistent with the protocol described by Tinetti.[18] Participants were allowed to use an assistive device if needed.

For the 5-m comfortable-walk test, participants were asked to walk at their self-selected speed. The time required to complete the middle 5 m of a 9-m walk was recorded using the average of 2 trials. Participants were allowed to use assistive devices during gait speed testing, and data collectors were allowed to provide as much physical assistance as needed, but no verbal cues were given (ie, verbal correction of gait deviations). If the participant was unable to complete a 5-m walk for any reason, their walking speed was scored as zero.

Data Analysis

Demographic data related to participant age, gender, FCI scores, days poststroke, length of stay in rehabilitation hospital, and location of stroke were analyzed using descriptive statistics including mean, standard deviation (SD), median, and frequency. Test-retest reliability was analyzed using $ICC_{2,1}$ where both subjects and raters are considered random. The POMA scores taken at initial admission to inpatient rehabilitation and 1 day later were used to calculate test-retest reliability. The $MDC_{95\%}$ was calculated using the formula described by Haley et al,[24] wherein $MDC_{95\%} = 1.96 \times SEM \times \sqrt{2}$. The standard error of the mean (SEM) was calculated using the formula $SD \times \sqrt{[1 - r]}$, where SD is the standard deviation of the baseline POMA scores, and r is the test-retest reliability coefficient. In general, ICC values of greater than 0.75 have been described as indicating good to excellent reliability.[41,42]

Cross-sectional construct validity of the POMA was determined by examining the relationship between POMA scores and gait speed, as well as POMA scores and motor FIM scores at both admission and discharge, using Spearman ρ (r_s) for ordinal data. Longitudinal construct validity was evaluated by examining the relationship between the change in all 3 outcome measures between admission and discharge, using Spearman ρ. Cohen[43] suggests that correlation coefficients of 0.10 or less indicate a fair relationship, 0.30 indicates a moderate relationship, and greater than 0.50 indicates a strong relationship.

RESULTS

Fifty-five people, 29 men and 26 women, participated in the study. The participants had a mean age of 75.7 ± 10.8 years and were an average of 8.2 ± 5.1 days poststroke at admission to the inpatient rehabilitation facility. Participants received inpatient physical therapy for an average of 23 days, which is slightly longer than the national average length of stay of 15 days.[44] The most frequently occurring comorbidities as measured by the FCI were arthritis, obesity, and diabetes, with a mean FCI score of 1.4 ± 1.3 for the cohort. The low number of average comorbidities within the cohort indicates that the difficulty with physical functioning exhibited by this sample may be likely to be more related to the acute stroke rather than to the comorbidities. Detailed information about participant characteristics and mean scores on outcome measures for all participants are given in Table 1.

The mean score on the first trial of the POMA taken at admission was 5.6 ± 5.2 points, and the mean score on the second trial taken at admission was 7.3 ± 5.6 points. The $ICC_{2,1}$ for the POMA was 0.839, and the MDC was 6 points, see Table 2.

Spearman ρ correlation coefficients revealed a moderate correlation between motor FIM scores and POMA scores and other outcome measures at both admission and discharge. The individual balance and gait components of the POMA were also moderately correlated with comfortable gait speed and motor FIM scores at both admission and discharge. Relationships between the variables was moderate and positive in direction ranging from $r_s = 0.54$ to 0.82, indicating cross-sectional validity of the POMA with both the motor FIM and gait speed when used in people with stroke, during inpatient rehabilitation. The correlation coefficients for all admission and discharge variables are given in Table 3.

Table 1. Participant Characteristics and Outcome Measures Scores (n = 55)

Age, mean (SD), y	75.7 (10.8)		
Gender, men/women	29/26		
Stroke location			
Cortical	30		
Subcortical	16		
Cerebellum	4		
Brainstem	5		
Side of hemiparesis			
Right	26		
Left	25		
Bilateral	4		
Length of stay, mean (SD), days	22.4 (10.6)		
Days poststroke at admission, mean (SD)	8.2 (5.1)		
Days poststroke at discharge, mean (SD)	30.0 (12.4)		
Mean Outcome Measures Scores	**Admission**	**Discharge**	**Change**
Tinetti POMA, mean (SD), range: 0-28	6.5 (5.2)	16.2 (6.1)	10.6 (6.1)
Gait speed, 5MWT, mean (SD), range: 0-∞	0.19 (0.21)	0.51 (0.32)	0.32 (0.28)
Motor FIM, mean (SD), range: 13-91	38.8 (10.9)	60.0 (11.3)	21.2 (11.3)

Abbreviations: 5MWT, 5-m Walk Test; FIM, Functional Independence Measure; POMA, Performance-Oriented Mobility Assessment.

Table 2. Tinetti POMA Test-Retest Reliability and MDC Values

	Trial 1, Mean (SD)	Trial 2, Mean (SD)	$ICC_{2,1}$ (95% CI)	$MDC_{95\%}$, Points
Tinetti POMA	5.6 (5.2)	7.3 (5.6)	0.839 (0.739-0.903)	6
Balance POMA	2.7 (3.2)	3.5 (3.4)	0.827 (0.721-0.895)	3
Gait POMA	3.1 (2.8)	4.0 (2.9)	0.829 (0.724-0.897)	3

Abbreviations: CI, confidence interval; ICC, intraclass correlation coefficient; MDC, minimal detectable change; POMA: Performance-Oriented Mobility Assessment.

There was a fair relationship between change scores on all 3 outcome measures, indicating adequate longitudinal construct validity of the POMA when used to measure balance early after stroke.

DISCUSSION

The results of this study demonstrate that the POMA has good ($ICC_{2,1} = 0.84$) test-retest reliability when used to measure balance in people who are in the first month following stroke. Test-retest reliability was similar to that found in older adults residing in long-term care facilities ($R = 0.72$).[21,45] This study exhibited slightly lower ICC values than found in people with chronic stroke (ICC = 0.91)[46] and community-dwelling people in the early stages of amyotrophic lateral sclerosis (ICC > 0.90).[22] This sample exhibited variability in performance on the test, which could contribute to lower test-retest reliability than is found in people with more chronic neurological disorders.

The MDC was estimated at 6 points, indicating that a patient must have a greater than 6-point change to be reflective of a true change in balance ability, as measured by the POMA. These results are similar to the estimated 5-point MDC on the POMA for older adults.[21] This is the first study to estimate MDC in people within the first month after stroke. Physical therapists can use this information as a guideline to set reasonable functional goals for their patients after stroke and to accurately interpret change in balance ability. Physical performance after stroke is highly variable, leading to the possibility that MDC may be overestimated. That is, people who changed less than 6 points on the POMA may have indeed had true change in performance. In this sample, 42 participants (76%) achieved MDC on the POMA. Additional MDC estimates should be conducted in samples of people with stroke who have similar attributes such as the amount of physical assistance needed for mobility. For example, within the first month after stroke, MDC estimates for people who require minimal assistance with transfers may be different from MDC estimates for those who do not need any physical assistance.

Table 3. Cross-Sectional and Longitudinal Construct Validity of the Tinetti POMA[a]

	Tinetti POMA	Balance Domain	Gait Domain
Admission			
Motor FIM	0.688	0.616	0.610
Gait speed	0.703	0.554	0.673
Discharge			
Motor FIM	0.609	0.588	0.536
Gait speed	0.770	0.638	0.816
Change[b]			
Motor FIM	0.389	0.277	0.396
Gait Speed	0.493	0.399	0.514

Abbreviation: FIM, Functional Independence Measure.
[a]All correlations significant $P < 0.05$, Spearman ρ (r_S).
[b]Change score = discharge score − admission score.

This is the first study to evaluate the validity of the POMA to measure functional performance in people early after stroke. Cross-sectional correlations revealed that POMA is a valid measurement tool for evaluating functional ability in people early after stroke, as indicated by a moderate relationship at both admission and discharge between POMA, gait speed, and motor FIM.[41] The amount of change on the POMA was most highly correlated with gait speed. This is likely because the gait component of the POMA measures some temporal aspects of gait such as step length, which are related to gait speed.[47] Similar to our findings, a moderate relationship between the POMA and gait speed has also been found in persons with Parkinson disease.[23] Our results are also similar to studies that examined the relationship of the BBS with both gait speed and motor FIM scores in people early after stroke.[48] Furthermore, the results support longitudinal validity of the POMA, indicating that it is sensitive to change and scores improve as gait speed and motor FIM scores improve.

Using the POMA to measure balance ability in people early after stroke has advantages over other commonly used balance measurement tools such as the BBS and the TUG. The BBS[15,49] measures balance ability in static positions and during transitional movement but does not assess indicators of balance during walking. The POMA measures some of the items within the BBS, such as sitting balance, static standing balance, and transitional movement from a chair to standing, and also adds an assessment of balance during the forward progression of walking. Furthermore, the POMA measures reactive balance, which is frequently affected in people with stroke, by assessing tolerance to a perturbation while standing. The BBS does not address reactive balance. In addition, the BBS has a documented floor effect when used with people early after stroke.[49,50] There were 5 of 55 or 9% of participants in this study who scored the lowest possible score at admission, indicating a low potential for floor effect when using the POMA early after stroke. No ceiling effect was found at either admission or discharge from inpatient rehabilitation.

The TUG requires the participant to rise from a chair and walk unassisted. The POMA captures whether assistance is needed during the transition from sit to stand. Thirty-five of 55 participants (65%) in this study required physical assistance from a caregiver for the sit-to-stand transition. It would not have been possible to test these participants by using the TUG.

Gait variability has been associated with balance deficits during walking and increased risk of falling.[51-53] The POMA captures asymmetry during gait that is often seen in people with stroke, as well as aspects of balance during gait, such as path deviation, trunk sway, and base of support. In contrast, the TUG does not measure specific aspects of balance during walking. Physical therapists can use this information provided by the POMA to formulate specific interventions to address these deviations, which negatively influence balance during walking. For example, if a patient exhibits excessive trunk sway and increased base of support during the test, the physical therapist can design balance interventions that require the patient to maintain center of gravity over a narrowed base of support. A potential strength of this study is that the tests were administered by physical therapists. The data were collected in a real-time inpatient rehabilitation setting, not a laboratory setting, which may improve generalizability of the results to people with stroke being treated in this environment.

LIMITATIONS

A testing interval of 1 day between trials was chosen to decrease the practice and learning effect that can occur with repeated testing. However, there is a possibility that because of the variability in functional ability of people early after stroke and the rapid gains usually made during inpatient physical therapy, the participants had an improvement in balance ability during the 24-hour test-retest interval. Certainly, this risk was reduced by choosing a smaller test-retest interval than the conventionally recommended to reduce practice effect, which has been reported as 1 week or more.[41] A 1-day testing interval may introduce rater bias because of the possibility that the rater may remember test scores from 1 day to the next. Raters were not blinded during testing, which may contribute to rater bias.

Minimal detectable change has not been previously reported for the POMA in persons with stroke. Our estimate of MDC on the POMA for acute stroke is similar for older adults.[21] For this sample, SDs and range were similar from admission to discharge, indicating that there was an overall increase in the scores, but there was variability between subjects both at admission and at discharge. Because the MDC is based on SEM, which is based on the SD, the large variability in the sample may have overestimated the MDC. Therefore, because of the large amount of variability in the sample, some participants who achieved less than a 6-point change on the POMA may have experienced true change in balance ability.

CONCLUSIONS

The results of this study demonstrate that the POMA is a valid and reliable tool to measure balance ability in people early after stroke. To be confident that a real change in balance ability has occurred in people early after stroke who are undergoing inpatient rehabilitation, a 6-point change on the POMA is needed. The POMA measures aspects of balance not captured by other commonly used tests such as the BBS and the TUG. On the basis of these results, the POMA should be used in clinical practice to measure areas of balance that are commonly affected in people early after stroke, such as balance difficulty during walking and deficits in reactive balance. Future research should be conducted to evaluate the validity and reliability of the POMA for use in people with chronic stroke, to determine clinically meaningful change on the POMA, and to assess the ability of the POMA to predict fall risk in people early after stroke.

REFERENCES

1. Tyson SF HM, Chillala J, Selley A, Tallis RC. Balance disability after stroke. *Phys Ther*. 2006;86(1):30-38.
2. Corriveau H, Herbert R, Raiche M, Prince F. Evaluation of postural stability in the elderly with stroke. *Arch Phys Med Rehabil*. 2004;85(7):1095-1101.
3. Sackley C. The relationship between weight-bearing asymmetry after stroke, motor function and activities of daily living. *Physiother Theory Pract*. 1990;6:179-185.
4. Michael K, Allen J, Macko R. Reduced ambulatory activity after stroke: the role of balance, gait and cardiovascular fitness. *Arch Phys Med Rehabil*. 2005;86:1552-1556.
5. Patterson S, Forrester L, Rodgers M, et al. Determinants of walking function after stroke: differences by deficit severity. *Arch Phys Med Rehabil*. 2007;88:115-119.
6. Pollock A, Durward B, Rowe P, Paul J. What is balance? *Clin Rehabil*. 2000;14:402-406.
7. Maki B, McIlroy W. The role of limb movements in maintaining upright stance: the "change-in-support" strategy. *Phys Ther*. 1997;77:488-507.
8. Badke M, Duncan P. Patterns of rapid motor responses during postural adjustments when standing in healthy subjects and hemiplegic patients. *Phys Ther*. 1983;63:13-20.
9. DiFabio R, Badke M, Duncan P. Adapting human postural reflexes following localized cerebrovascular lesion: analysis of bilateral long latency responses. *Brain Res*. 1986;363:257-264.
10. Luchies C, Alexander N, Schultz A, Ashton-Miller J. Stepping responses of young and old adults to postural disturbances: kinematics. *J Am Geriatr Soc*. 1994;42:506-512.
11. Maki B, Edmondstone M, Perry S, Heung E, Quant S, McIlroy W. Control of rapid limb movements for balance recovery: do age-related changes predict falling risk? In: Duysens J, Smits-Engelsman BCM, Kingma H, eds. *Control of Posture and Gait*. Maasstricht, the Netherlands: International Society for Posture and Gait Research; 2001:126-129.
12. Lakhani B, Mansfield A, Inness E, McIlroy W. Compensatory stepping responses in individuals with stroke: a pilot study. *Physiother Theory Pract*. 2011;27(4):299-309.
13. Berg K, Wood-Dauphinee S, Williams JI. The balance scale: reliability assessment for elderly residents and patients with an acute stroke. *Scand J Rehabil Med*. 1995;27:27-36.
14. Berg KO, Wood-Dauphinee SL, Williams JI, Maki B. Measuring balance in the elderly: validation of an instrument. *Can J Public Health*. 1992;83(suppl 2):S7-S11.

15. Blum L, Korner-Bitensky N. Usefulness of the Berg Balance Scale in stroke rehabilitation: a systematic review. *Phys Ther*. 2008;88(5):559-566.
16. Flansbjer U, Holmba¨ck A, Downham D, Patten C, Lexell J. Reliability of gait performance tests in men and women with hemiparesis after stroke. *J Rehabil Med*. 2005;37:75-82.
17. Ng S, Hui-Chan C. The Timed Up and Go test: its reliability and association with lower-limb impairments and locomotor capacities in people with chronic stroke. *Arch Phys Med Rehabil*. 2005;86(8):1641-1647.
18. Tinetti M. Performance-oriented assessment of mobility problems in elderly patients. *J Am Geriatr Soc*. 1986;34:119-126.
19. Harada N, Chiu V, Damron-Rodriguez J, Fowler E, Sui A, Reuben D. Screening for balance and mobility impairment in elderly individuals living in residential care facilities. *Phys Ther*. 1995;75:462-469.
20. Tinetti M, Williams T, Mayewski R. Fall risk index for elderly patients based on number of chronic disabilities. *Am J Med*. 1993;80:429-434.
21. Faber M, Bosscher R, van Wieringen P. Clinometric properties of the Performance Oriented Mobility Assessment. *Phys Ther*. 2006;86(7):944-954.
22. Kloos A, Bello-Haas V, Thome R, et al. Interrater and intrarater reliability of the Tinetti Balance Test for individuals with amyotrophic lateral sclerosis. *J Neurol Phys Ther*. 2004;28(1):12-19.
23. Kegelmeyer D, Kloos A, Thomas K, Kostyk S. Reliability and validity of the Tinetti Mobility Test for individuals with Parkinson disease. *Phys Ther*. 2007;87(10):1369-1378.
24. Haley SM F-PM S. Interpreting change scores of tests and measures used in physical therapy. *Physical Therapy*. 2006;86(5):735-743.
25. Groll D, Tob T, Bombardierc C, Wright J. The development of a comorbidity index with physical function as the outcome. *J Clin Epidemiol*. 2005;58:595-602.
26. Goldie P, Matyas T, Evans O. Deficit and change in gait velocity during rehabilitation after stroke. *Arch Phys Med Rehabil*. 1996;77:1074-1082.
27. Fulk G, Echternach J. Test-retest reliability and minimal detectable change of gait speed in individuals undergoing rehabilitation after stroke. *J Neurol Phys Ther*. 2008;32:8-13.
28. Salbach N, Mayo N, Higgins J, Ahmed S, Finch L, Richards C. Responsiveness and predictability of gait speed and other disability measures in acute stroke. *Arch Phys Med Rehabil*. 2001;82:1204-1212.
29. Collen F, Wade E, Bradshaw C. Mobility after stroke: reliability of measures of impairment and disability. *Int Disabil Stud*. 1990;12:6-9.
30. VanSwearingen J, Paschcal K, Bonino P, Chen T. Assessing recurrent fall risk of community-dwelling, frail older veterans using specific tests of mobility and the physical performance test of function. *J Gerontol A Biol Sci Med Sci*. 1998;53:M457-M464.
31. Tilson J, Sullivan K, Cen S, et al. Meaningful gait speed improvement during the first 60 days poststroke: minimal clinically important difference. *Phys Ther*. 2010;90(2):1-13.
32. Fulk G, Ludwig M, Dunning K, Golden S, Boyne P, West T. Estimating clinically important change in gait speed in people with stroke undergoing outpatient rehabilitation. *J Neurol Phys Ther*. 2011;35:82-89.
33. Wallace D, Duncan P, MinLai S. Comparison of the responsiveness of the Barthel Index and the motor component of the Functional Independence Measure in stroke. *J Clin Epidemiol*. 2002;55:922-928.
34. Kidd D, Stewart G, Baldry J, et al. The Functional Independence Measure—A comparative validity and reliability study. *Disabil Rehabil*. 1995;17(1):10-14.
35. Van Der Putten J, Hobart J, Freeman J, Thompson A. Measuring change in disability after inpatient rehabilitation: comparison of the responsiveness of the Barthel Index and the Functional Independence Measure. *J Neurol Neurosurg Psychiatry*. 1999;66:480-484.
36. Hsueh I, Lin J, Jeng J, Hsieh C. Comparison of the psychometric characteristics of the Functional Independence Measure, 5 item Barthel Index and 10 item Barthel Index in patients with stroke. *J Neurol Neurosurg Psychiatry*. 2002;73:188-190.
37. Granger CV, Cotter AC, Hamilton BB, Fiedler RC. Functional assessment scales: a study of persons after stroke. *Arch Phys Med Rehabil*. 1993;74:133-138.
38. Hobart J, Lamping D, Freeman J, Langdon D, McClellen R. Evidenced based measurement: which disability scale for neurologic rehabilitation? *Neurology*. 2001;57:639-644.
39. Ring H, Feder M, Schwartz J, Samuels G. Functional measures of first stroke rehabilitation inpatients: usefulness of the Functional Independence Measure total score. *Arch Phys Med Rehabil*. 1997;78(6):630-635.
40. Tur B, Gursel Y, Yavuzer G, Kucukdeveci A, Arasil T. Rehabilitation outcome of Turkish stroke patients: in a team approach setting. *Int J Rehabil Res*. 2003;26:271-277.
41. Portney L, Watkins M. *Foundations of Clinical Research: Application to Practice*. 3rd ed. Upper Saddle River, NJ: Pearson Prentice Hall; 2009.
42. Fleiss J. *The Design and Analysis of Clinical Experiments*. New York, NY: Wiley; 1986.
43. Cohen J. *Statistical Power Analysis for the Behavioral Sciences*. 2nd ed. Hillsdale, NJ: Erlbaum; 1988.
44. Conroy B, DeJong G, Horn S. Hospital based rehabilitation in the United States. *Top Stroke Rehabil*. 2009;16(1):34-43.
45. Purushottam B, Gideon P, Brockman K, Fought K, Ray W. Clinical and biomechanical measures of balance fall predictors in ambulatory nursing home residents. *J Gerontol A Biol Sci Med Sci*. 1996;51A(5):M239-M246.
46. Daly J, Roenigk K, Holcomb J, et al. A randomized controlled trial of functional neuromuscular stimulation in chronic stroke patients. *Stroke*. 2006;37:172-178.
47. Roth E, Merbitz C, Mroczek K, Dugan S, Suh W. Hemiplegic gait: relationships between walking speed and other temporal measures. *Am J Phys Med Rehabil*. 1997;76(2):128-133.
48. Richards C, Malouin F, Dumas F, Tardif O. Gait velocity as an outcome measure of locomotor recovery after stroke. In: Craik R, Oatis C, eds. *Gait Analysis: Theory and Applications*. St Louis, MO: Mosby; 1995:355-364.
49. Mao H, Hsueh I, Tang P, et al. Analysis and comparison of the psychometric properties of three balance measures for stroke patients. *Stroke*. 2002;33:1022-1027.
50. Chou C, Chien C, Hsueh I, et al. Developing a short form of the Berg Balance Scale for people with stroke. *Phys Ther*. 2006;86:195-204.
51. Verma R, Arya K, Sharma P, Garg R. Understanding gait control in post-stroke: implications for management. *J Bodywork Movement Ther*. 2012;16:14-21.
52. Brach J, Berlin J, VanSwearingen J, Newman A, SA S. Too much or too little step width variability is associated with a fall history in older persons who walk at or near normal gait speed. *J Neuroeng Rehabil*. 2005;2:21.
53. Hausdorff J, Rios D, Edelberg H. Gait variability and fall risk in community-living older adults: a 1-year prospective study *Arch Phys Med Rehabil*. 2001;82:1050-1056.