Brain Neurorehabil. 2022 Jul;15(2):e17
https://doi.org/10.12786/bn.2022.15.e17
pISSN 1976-8753·eISSN 2383-9910

Brain & NeuroRehabilitation

Special Review

Functional Assessment in Neurorehabilitation

Check for updates

Assessment of Lower Limb Motor Function, Ambulation, and Balance After Stroke

OPEN ACCESS

Yeun Jie Yoo, Seong Hoon Lim

Received: May 18, 2022
Revised: Jul 4, 2022
Accepted: Jul 6, 2022
Published online: Jul 13, 2022

Correspondence to
Seong Hoon Lim
Department of Rehabilitation Medicine, St. Vincent's Hospital, College of Medicine, The Catholic University of Korea, 93 Jungbu-daero, Paldal-gu, Suwon 16247, Korea.
Email: seonghoon@catholic.ac.kr

HIGHLIGHTS

- For motor function, we reviewed Motricity Index and Fugl-Meyer Assessment.
- For walking, we reviewed Functional Ambulation Category, 10-m, and 6-minute Walk Test.
- For balance, Berg Balance Scale, Timed Up and Go, Functional Reach Test, and Trunk Impairment Scale were reviewed.

Brain Neurorehabil. 2022 Jul;15(2):e17
https://doi.org/10.12786/bn.2022.15.e17
pISSN 1976-8753·eISSN 2383-9910

Brain & NeuroRehabilitation

Special Review

Functional Assessment in Neurorehabilitation

Check for updates

Assessment of Lower Limb Motor Function, Ambulation, and Balance After Stroke

Yeun Jie Yoo, **Seong Hoon Lim**

Department of Rehabilitation Medicine, St. Vincent's Hospital, College of Medicine, The Catholic University of Korea, Seoul, Korea

Received: May 18, 2022
Revised: Jul 4, 2022
Accepted: Jul 6, 2022
Published online: Jul 13, 2022

Correspondence to
Seong Hoon Lim
Department of Rehabilitation Medicine, St. Vincent's Hospital, College of Medicine, The Catholic University of Korea, 93 Jungbu-daero, Paldal-gu, Suwon 16247, Korea.
Email: seonghoon@catholic.ac.kr

ORCID iDs
Yeun Jie Yoo
https://orcid.org/0000-0003-1323-4503
Seong Hoon Lim
https://orcid.org/0000-0002-5475-4153

Funding
This work was supported by the National Research Foundation of Korea funded by the Korean government (No. NRF 2021R1A2C1012113).

ABSTRACT

Restoration of ambulation is important for stroke patients. Valid and reliable methods are required for the assessment of lower limb functional status. We reviewed the psychometric properties of methods employed to assess lower extremity motor function, ambulation, and balance, with a focus on stroke patients. We define "motor function" as the ability to produce bodily movements when the brain, motor neurons, and muscles interact. "Ambulation" is defined as the ability to walk with or without a personal assistive device, and "balance" as the ability to maintain stability (without falling) during various physical activities. The Motricity Index and Fugl-Meyer Assessment of Lower Extremities assess the motor function of the lower limbs. The Functional Ambulation Category, 10-m Walk Test, and 6-minute Walk Test assess ambulation. The Berg Balance Scale, Timed Up and Go Test, Functional Reach Test, and Trunk Impairment Scale explore balance. All these tests exhibit high-level validity and have good inter-rater and test-retest reliabilities. However, only 3 methods have been formally translated into Korean. The methods discussed here can be used for standardized assessment, personalized goal setting, rehabilitation planning, and estimation of therapeutic efficacy.

Keywords: Stroke; Postural Balance; Ambulation; Physical Functional Performance; Lower Extremity; Balance; Motor Function; Assessment

INTRODUCTION

Standing and ambulation employing the lower limbs are complex processes and are managed by high-level brain centers, whereas locomotor programming occurs at the level of the cerebral cortex in conjunction with the basal ganglia and cerebellum [1]. Motor impairments after stroke manifest as impaired muscle strength and tone as well as poor motor coordination, which also impair mobility. Following a stroke, spontaneous neurological recovery of motor function was found to plateau after progressive improvement in the first 3–6 months in previous longitudinal studies [2]. However, even after this period of active neuroplasticity, full restoration of motor function and ambulation remain key goals for many stroke patients. Rehabilitation seeks to restore locomotor function and help the patient to successfully return to society. To this end, it is necessary to identify and quantify the physical condition, set realistic goals, and plan a patient-tailored intervention strategy. Various

Conflict of Interest

The corresponding author of this manuscript is an editor of *Brain & NeuroRehabilitation*. The corresponding author did not engage in any part of the review and decision-making process for this manuscript. The other authors have no potential conflicts of interest to disclose.

evaluation tools have been developed to assess motor function, ambulation, and balance, but most are research-oriented and are difficult to apply in the clinic because of time, cost, and facility constraints. Furthermore, clinicians need reasonable clinical outcome measures that are both valid and reliable.

Here, we review the psychometric properties of tools assessing lower extremity motor function, ambulation, and balance, with a focus on stroke patients. We define "motor function" as the ability to produce bodily movements when the brain, motor neurons, and muscles interact. "Ambulation" is defined as the ability to walk with or without a personal assistive device, and "balance" as the ability to maintain stability (without falling) during various physical activities.

MOTOR FUNCTION ASSESSMENT METHODS

Motricity Index (MI)

The MI was developed in 1980 by Demeurisse et al. [3] to evaluate stroke patients with hemiplegia. With this index, muscle strength is assessed by analyzing single essential movements of all joints of the upper and lower extremities. The MI can be used to rapidly assess impairment, but potential ceiling effects have been reported [4]. The test is a modification of the Medical Research Council (MRC) system in which the MI evaluates the strengths of 6 muscles. To evaluate the upper extremities, the pinch grip, elbow flexion, and shoulder abduction are tested; for the lower extremities, ankle dorsiflexion, knee extension, and hip flexion are explored. Muscle activity is divided into 6 grades (using the ordinal MRC scale) that are converted to weighted scores. For each joint, the score ranges from 0 (no movement) to 33 (normal power); the total score thus has a range of 0–99 for the combined extremities. The MI exhibits excellent inter-rater and test-retest reliabilities in patients with chronic stroke [5,6]. The test validity was high when the isometric strength of the same muscle was measured using a hand-held dynamometer [7], and the MI has been employed to measure responsiveness in research scenarios [8,9]. However, the minimal clinically important difference (MCID) has not yet been established.

Fugl-Meyer Assessment of Lower Extremity (FMA-LE)

The FMA was established in 1975 to evaluate the recovery of sensorimotor function in stroke patients [10]. The FMA-LE explores hip, knee, and ankle movements, and hierarchical recovery from reflexive to synergic and non-synergic movements based on the Brunnstrom recovery stage is recorded. The FMA-LE motor domain uses a 3-point ordinal scale as follows: 0, unable to perform; 1, partially performance; and 2, complete performance. The possible score ranges from 0 to 34. Patient coordination, sensory function, joint range of motion, and joint pain are also assessed. The FMA has been widely used to evaluate stroke patients, but potential floor and ceiling effects have been reported [11]. The inter-rater and test-retest reliabilities were excellent in early, subacute, and chronic stroke patients [11-13]. Several studies have evaluated the assessment validity and found that the scores were correlated with measures of the activities of daily living or walking performance [14,15]. Although evidence on criterion validity is lacking, the FMA-LE score at admission predicted mobility on discharge [16]. However, FMA-LE responsiveness was low to moderate during inpatient rehabilitation of stroke patients [11]. The MCID of the FMA-LE in terms of both the Functional Ambulation Category (FAC) and a global rating of patient-perceived change was 6 points in chronic stroke patients [17].

bnr Brain & NeuroRehabilitation

AMBULATION ASSESSMENT METHODS

FAC

The FAC was developed by Holden et al. in 1984 [18]. The 6-point scale assesses how much human support is needed (regardless of whether a personal assistive device is used) when walking. The FAC can be quickly evaluated in clinical practice and has been used to assess patients suffering from stroke or other neurological conditions. A score of 0 indicates a non-functional ambulator, and scores of 1–3 indicate dependent ambulators. A score of 1 indicates the need for continuous manual contact, a score of 2 intermittent or continuous light touching, and a score of 3 supervision or verbal cueing. Those with scores of 4–5 are independent ambulators, with a score of 4 indicating independent ambulation only on level surfaces and a score of 5 indicating independent ambulation on any surface including stairs. Mehrholz et al. [19] reported excellent inter-rater and test-retest reliabilities in patients with subacute stroke. The FAC exhibited good construct validity compared to the Rivermead Mobility Index, the 6-minute Walk Test (6minWT), and gait parameters. An FAC score of 4 or higher after 4 weeks of rehabilitation predicted functional ambulation after 6 months. The MCID of the FAC is unknown.

The 10-m Walk Test (10mWT)

The 10mWT calculates walking speed by measuring the time taken to walk 10 m at a speed selected by the patient. The test is repeated 3 times (with 30-seccond gaps between each pair of tests) and an average calculated. A personal assistive device can be used; additional acceleration and deceleration phases are permitted and are not used when determining speed. Although the test is applicable only when a patient can in fact walk 10 m, the test rapidly evaluates ambulation and is widely used to assess stroke patients, those with brain injuries and neurodegenerative and musculoskeletal diseases, and healthy populations.

The 10mWT exhibits excellent inter-rater and test-retest reliabilities [20,21] and excellent correlations with the 6minWT results of stroke patients, confirming its construct validity [22]. As a comfortable walking speed is selected, the test reflects real-world ambulation, although responsiveness has been little studied. Assessment employing the modified Rankin Scale to evaluate stroke patients yielded an MCID of 0.16 m/s [23]. The cut-off values for ambulatory ability based the walking speed of stroke patients were < 0.4 m/s for household ambulators, 0.4–0.8 m/s for limited community ambulators, and > 0.8 m/s for community ambulators [24].

The 6minWT

The 6minWT evaluates submaximal aerobic capacity; the patient walks as far as possible on a flat 30-m-long corridor for 6 minutes at a self-paced speed. The principal outcome is the distance walked in meters. A personal assistive device or supplemental oxygen can be used during examination, and safety is ensured by continuous monitoring of oxyhemoglobin saturation, the heart rate, and the Borg Dyspnea Scale. The test is used principally to measure cardiopulmonary endurance and treatment outcomes in patients with cardiopulmonary diseases but has also been employed to measure gait performance in patients with various neurological diseases including stroke and healthy populations. However, like the 10mWT, the patient must be able to walk independently without the risk of falling. The test evidenced excellent test-retest reliability in patients with acute-to-chronic stroke [20,22] and excellent inter-rater reliability in patients with acute-to-subacute stroke [25]. The construct validity was excellent in comparison with other gait performance tests (the 10mWT, Timed Up and Go [TUG] Test) in patients with chronic stroke [20]. However, the distance traveled seems to be not or weakly correlated with the maximum oxygen consumption of stroke patients, such that the distance traveled appears to (principally) reflect balance [26,27]. Therefore, caution is needed when interpreting the 6minWT distance as indicative of aerobic capacity. Responsiveness was associated with gait training and inpatient rehabilitation of patients with subacute-to-chronic stroke [25,28]. The MCID of the 6minWT in stroke patients is unknown.

BALANCE ASSESEMENT METHODS

The Berg Balance Scale (BBS)

The BBS was developed by Katherine Berg in 1989 after a 3-step survey of 32 healthcare professionals to objectively measure the balance and fall risk of community-dwelling elderly people. The BBS explores 14 movements of daily life on a 5-point ordinal scale (range 0–4). A score of 0 indicates the lowest functional level and a score of 4 normal performance; the total score range is 0–56. In a study on community-dwelling elderly people, those with BBS scores greater than 45 were at increased risk of falls [29]. The BBS is widely used to assess stroke patients, and its inter-rater and test-retest reliabilities were excellent in patients with acute and chronic stroke [30-32]. Good-to-excellent construct validity was apparent on comparison with other balance measures including the Postural Assessment Scale for Stroke and the Functional Reach Test (FRT) [33,34]. Mao et al. [33] reported that the BBS exhibited excellent predictive validity compared to the walking subscale of the Motor Assessment Scale and was moderately-to-highly responsive to changes in the initial 14 to 90 days after stroke onset. In a recent study, the MCID of the BBS correlated with an increase of 1 point or more in the FAC in patients with early subacute stroke, but with increases of 5 points in those requiring walking assistance. Further evaluation is required [35].

TUG Test

The TUG Test is a modification of the "Get Up and Go" test of Mathias et al. [36] that measures balance and functional ambulation in the frail elderly. A chair with a back and an arm rest is placed at the end of a 3-m walkway. The examiner measures the time (in seconds) that elapses when a subject gets up from the chair, walks 3 m, turns, walks back to the chair, and sits down, with or without a personal assistive device. The TUG Test is widely used to evaluate the elderly, stroke patients, and patients with Parkinson's disease, traumatic brain injury, and several musculoskeletal diseases. The TUG Test exhibited excellent inter-rater and test-retest reliabilities in patients with acute-to-chronic stroke [20,37]. Good-to-excellent construct validity was apparent in patients with subacute-to-chronic stroke compared to other measures including the BBS, 10mWT, and 6minWT [20,38,39]. In stroke patients, the difference in TUG Test times between fallers and non-fallers was significant, but it was not clear whether the TUG Test can predict fall risk [40-42]. In acute stroke patients, one study observed good responsiveness in patients with moderate-to-fast walking speeds [43]. The MCID of the TUG Test in stroke patients is unknown.

FRT

The FRT was developed in 1990 by Duncan et al. [44] to simply measure dynamic balance in the frail elderly. The patient stands perpendicular to a wall with the shoulders adjacent to the wall and raises the hands forward through 90 degrees. The examiner measures the maximal distance to which the subject can extend the hands forward without lifting a foot.

The FRT has been widely used to predict fall risk, principally in the frail elderly [45]. Katz-Leurer et al. [46] developed a modified FRT in which patients with impaired balance (such as stroke patients) sit and reported a significant (but moderate) correlation to results from a computerized force platform. The FRT is simple in terms of time, space, and cost, and reliably evaluates ambulatory ability and fall risk. The modified FRT exhibited excellent test-retest reliability and responsiveness in patients with subacute stroke. A moderate-to-good correlation between the FRT and BBS was reported in stroke patients [47]. The MCID of the FRT remains unknown.

Trunk Impairment Scale (TIS)

The TIS was developed in 2004 by Verheyden et al. [48] to measure motor impairment of the trunk after stroke. It has 3 subscales with 3–10 items in each subscale to measure static and dynamic balance and trunk coordination in a sitting position; the total score range is 0–23. Patients were instructed to cross legs, lean against a table, lift the pelvis, and rotate the trunk without losing balance in sitting position. The TIS showed excellent test-retest and inter-rater reliability in subacute to chronic stroke patients [48]. Compared with Barthel Index, excellent construct validity was established [48]. Concurrent validity compared with the Trunk Control Test and Postural Assessment Scale was also excellent [48,49]. Because trunk stability plays an important role in performing activities of daily living, TIS predict Functional Independent Measure score at discharge and Barthel Index after 6 months in acute stroke patients [49,50]. The responsiveness and MCID of TIS is not well established.

CONCLUSION

Table 1 summarizes the characteristics and original languages of all methods, and states whether Korean versions are available. Stroke patients exhibit varying extents of motor function, ambulation, and balance impairment. Although various evaluation tools have been developed for such patient, standardized methods are still needed to quantify functional disability before and after treatment. It would then be possible to tailor treatment for each patient. Further research is needed to establish a scoring system that reflects the real physical disabilities of stroke patients.

Table 1. Psychometric properties and Korean translation status of measures of lower extremity motor function, walking, and balance

Measure	Original language	Korean translation?	Inter-rater reliability	Test-retest reliability	Validity
MI	English	X	O	O	O
FMA-LE	English	O*	O	O	O
FAC	English	X	O	O	O
10mWT	English	X	O	O	O
6minWT	English	X	O	O	O
BBS	English	O†	O	O	O
TUG Test	English	X	O	O	O
FRT	English	X	O	O	O
TIS	English	O‡	O	O	O

MI, Motricity Index; FMA-LE, Fugl-Meyer Assessment of Lower Extremity; FAC, Functional Ambulation Category; 10mWT, 10-m Walk Test; 6minWT, 6-minute Walk Test; BBS, Berg Balance Scale; TUG, Timed Up and Go; FRT, Functional Reach Test; TIS, Trunk Impairment Scale.
*Translation into Korean was done by Kim et al. [51].
†Translation into Korean was done by Jung et al. [52].
‡Translation into Korean was done by Seo et al. [53].

REFERENCES

1. Takakusaki K. Neurophysiology of gait: from the spinal cord to the frontal lobe. Mov Disord 2013;28:1483-1491.
PUBMED | CROSSREF
2. Jørgensen HS, Nakayama H, Raaschou HO, Vive-Larsen J, Støier M, Olsen TS. Outcome and time course of recovery in stroke. Part I: outcome. The Copenhagen Stroke Study. Arch Phys Med Rehabil 1995;76:399-405.
PUBMED | CROSSREF
3. Demeurisse G, Demol O, Robaye E. Motor evaluation in vascular hemiplegia. Eur Neurol 1980;19:382-389.
PUBMED | CROSSREF
4. Jacob-Lloyd HA, Dunn OM, Brain ND, Lamb SE. Effective measurement of the functional progress of stroke clients. Br J Occup Ther 2005;68:253-259.
CROSSREF
5. Collin C, Wade D. Assessing motor impairment after stroke: a pilot reliability study. J Neurol Neurosurg Psychiatry 1990;53:576-579.
PUBMED | CROSSREF
6. Fayazi M, Dehkordi SN, Dadgoo M, Salehi M. Test-retest reliability of Motricity Index strength assessments for lower extremity in post stroke hemiparesis. Med J Islam Repub Iran 2012;26:27-30.
PUBMED
7. Cameron D, Bohannon RW. Criterion validity of lower extremity Motricity Index scores. Clin Rehabil 2000;14:208-211.
PUBMED | CROSSREF
8. Smith J, Brotheridge S, Young J. Patterns of hemiparesis recovery in lacunar and partial anterior circulation infarct stroke syndromes. Clin Rehabil 2001;15:59-66.
PUBMED | CROSSREF
9. Wolfe CD, Tilling K, Rudd AG. The effectiveness of community-based rehabilitation for stroke patients who remain at home: a pilot randomized trial. Clin Rehabil 2000;14:563-569.
PUBMED | CROSSREF
10. Fugl-Meyer AR, Jääskö L, Leyman I, Olsson S, Steglind S. The post-stroke hemiplegic patient. 1. a method for evaluation of physical performance. Scand J Rehabil Med 1975;7:13-31.
PUBMED
11. Hsueh IP, Hsu MJ, Sheu CF, Lee S, Hsieh CL, Lin JH. Psychometric comparisons of 2 versions of the Fugl-Meyer Motor Scale and 2 versions of the Stroke Rehabilitation Assessment of Movement. Neurorehabil Neural Repair 2008;22:737-744.
PUBMED | CROSSREF
12. Duncan PW, Propst M, Nelson SG. Reliability of the Fugl-Meyer Assessment of sensorimotor recovery following cerebrovascular accident. Phys Ther 1983;63:1606-1610.
PUBMED | CROSSREF
13. Sanford J, Moreland J, Swanson LR, Stratford PW, Gowland C. Reliability of the Fugl-Meyer Assessment for testing motor performance in patients following stroke. Phys Ther 1993;73:447-454.
PUBMED | CROSSREF
14. Dettmann MA, Linder MT, Sepic SB. Relationships among walking performance, postural stability, and functional assessments of the hemiplegic patient. Am J Phys Med 1987;66:77-90.
PUBMED
15. Wood-Dauphinee SL, Williams JI, Shapiro SH. Examining outcome measures in a clinical study of stroke. Stroke 1990;21:731-739.
PUBMED | CROSSREF
16. Chae J, Johnston M, Kim H, Zorowitz R. Admission motor impairment as a predictor of physical disability after stroke rehabilitation. Am J Phys Med Rehabil 1995;74:218-223.
PUBMED | CROSSREF
17. Pandian S, Arya KN, Kumar D. Minimal clinically important difference of the lower-extremity Fugl-Meyer Assessment in chronic-stroke. Top Stroke Rehabil 2016;23:233-239.
PUBMED | CROSSREF
18. Holden MK, Gill KM, Magliozzi MR, Nathan J, Piehl-Baker L. Clinical gait assessment in the neurologically impaired. Reliability and meaningfulness. Phys Ther 1984;64:35-40.
PUBMED | CROSSREF
19. Mehrholz J, Wagner K, Rutte K, Meissner D, Pohl M. Predictive validity and responsiveness of the functional ambulation category in hemiparetic patients after stroke. Arch Phys Med Rehabil 2007;88:1314-1319.
PUBMED | CROSSREF

20. Flansbjer UB, Holmbäck AM, 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.
PUBMED | CROSSREF

21. Collen FM, Wade DT, Bradshaw CM. Mobility after stroke: reliability of measures of impairment and disability. Int Disabil Stud 1990;12:6-9.
PUBMED | CROSSREF

22. Cheng DK, Nelson M, Brooks D, Salbach NM. Validation of stroke-specific protocols for the 10-meter walk test and 6-minute walk test conducted using 15-meter and 30-meter walkways. Top Stroke Rehabil 2020;27:251-261.
PUBMED | CROSSREF

23. Tilson JK, Sullivan KJ, Cen SY, Rose DK, Koradia CH, Azen SP, Duncan PW; Locomotor Experience Applied Post Stroke (LEAPS) Investigative Team. Meaningful gait speed improvement during the first 60 days poststroke: minimal clinically important difference. Phys Ther 2010;90:196-208.
PUBMED | CROSSREF

24. Bowden MG, Balasubramanian CK, Behrman AL, Kautz SA. Validation of a speed-based classification system using quantitative measures of walking performance poststroke. Neurorehabil Neural Repair 2008;22:672-675.
PUBMED | CROSSREF

25. Kosak M, Smith T. Comparison of the 2-, 6-, and 12-minute walk tests in patients with stroke. J Rehabil Res Dev 2005;42:103-107.
PUBMED | CROSSREF

26. Pang MY, Eng JJ, Dawson AS. Relationship between ambulatory capacity and cardiorespiratory fitness in chronic stroke: influence of stroke-specific impairments. Chest 2005;127:495-501.
PUBMED | CROSSREF

27. Eng JJ, Dawson AS, Chu KS. Submaximal exercise in persons with stroke: test-retest reliability and concurrent validity with maximal oxygen consumption. Arch Phys Med Rehabil 2004;85:113-118.
PUBMED | CROSSREF

28. Rose DK, Nadeau SE, Wu SS, Tilson JK, Dobkin BH, Pei Q, Duncan PW. Locomotor training and strength and balance exercises for walking recovery after stroke: response to number of training sessions. Phys Ther 2017;97:1066-1074.
PUBMED | CROSSREF

29. Berg K. Measuring balance in the elderly: development and validation of an instrument [dissertation]. Montreal: McGill University; 1992.

30. Flansbjer UB, Blom J, Brogårdh C. The reproducibility of Berg Balance Scale and the Single-Leg Stance in chronic stroke and the relationship between the two tests. PM R 2012;4:165-170.
PUBMED | CROSSREF

31. Berg K, Wood-Dauphinee S, Williams JI. The Balance Scale: reliability assessment with elderly residents and patients with an acute stroke. Scand J Rehabil Med 1995;27:27-36.
PUBMED

32. Stevenson TJ. Detecting change in patients with stroke using the Berg Balance Scale. Aust J Physiother 2001;47:29-38.
PUBMED | CROSSREF

33. Mao HF, Hsueh IP, Tang PF, Sheu CF, Hsieh CL. Analysis and comparison of the psychometric properties of three balance measures for stroke patients. Stroke 2002;33:1022-1027.
PUBMED | CROSSREF

34. Smith PS, Hembree JA, Thompson ME. Berg Balance Scale and Functional Reach: determining the best clinical tool for individuals post acute stroke. Clin Rehabil 2004;18:811-818.
PUBMED | CROSSREF

35. Tamura S, Miyata K, Kobayashi S, Takeda R, Iwamoto H. The minimal clinically important difference in Berg Balance Scale scores among patients with early subacute stroke: a multicenter, retrospective, observational study. Top Stroke Rehabil 2022;29:423-429.
PUBMED | CROSSREF

36. Mathias S, Nayak US, Isaacs B. Balance in elderly patients: the "get-up and go" test. Arch Phys Med Rehabil 1986;67:387-389.
PUBMED

37. Lyders Johansen K, Derby Stistrup R, Skibdal Schjøtt C, Madsen J, Vinther A. Absolute and relative reliability of the Timed 'Up & Go'test and '30second Chair-Stand' test in hospitalised patients with stroke. PLoS One 2016;11:e0165663.
PUBMED | CROSSREF

38. Knorr S, Brouwer B, Garland SJ. Validity of the Community Balance and Mobility Scale in community-dwelling persons after stroke. Arch Phys Med Rehabil 2010;91:890-896.
PUBMED | CROSSREF

39. Chan PP, Si Tou JI, Tse MM, Ng SS. Reliability and validity of the timed up and go test with a motor task in people with chronic stroke. Arch Phys Med Rehabil 2017;98:2213-2220.
PUBMED | CROSSREF

40. Belgen B, Beninato M, Sullivan PE, Narielwalla K. The association of balance capacity and falls self-efficacy with history of falling in community-dwelling people with chronic stroke. Arch Phys Med Rehabil 2006;87:554-561.
PUBMED | CROSSREF

41. Andersson AG, Kamwendo K, Seiger A, Appelros P. How to identify potential fallers in a stroke unit: validity indexes of 4 test methods. J Rehabil Med 2006;38:186-191.
PUBMED | CROSSREF

42. Persson CU, Hansson PO, Sunnerhagen KS. Clinical tests performed in acute stroke identify the risk of falling during the first year: postural stroke study in Gothenburg (POSTGOT). J Rehabil Med 2011;43:348-353.
PUBMED | CROSSREF

43. Salbach NM, Mayo NE, Higgins J, Ahmed S, Finch LE, Richards CL. Responsiveness and predictability of gait speed and other disability measures in acute stroke. Arch Phys Med Rehabil 2001;82:1204-1212.
PUBMED | CROSSREF

44. Duncan PW, Weiner DK, Chandler J, Studenski S. Functional reach: a new clinical measure of balance. J Gerontol 1990;45:M192-M197.
PUBMED | CROSSREF

45. Weiner DK, Duncan PW, Chandler J, Studenski SA. Functional reach: a marker of physical frailty. J Am Geriatr Soc 1992;40:203-207.
PUBMED | CROSSREF

46. Katz-Leurer M, Fisher I, Neeb M, Schwartz I, Carmeli E. Reliability and validity of the modified functional reach test at the sub-acute stage post-stroke. Disabil Rehabil 2009;31:243-248.
PUBMED | CROSSREF

47. Tyson SF, DeSouza LH. Reliability and validity of functional balance tests post stroke. Clin Rehabil 2004;18:916-923.
PUBMED | CROSSREF

48. Verheyden G, Nieuwboer A, Mertin J, Preger R, Kiekens C, De Weerdt W. The Trunk Impairment Scale: a new tool to measure motor impairment of the trunk after stroke. Clin Rehabil 2004;18:326-334.
PUBMED | CROSSREF

49. Di Monaco M, Trucco M, Di Monaco R, Tappero R, Cavanna A. The relationship between initial trunk control or postural balance and inpatient rehabilitation outcome after stroke: a prospective comparative study. Clin Rehabil 2010;24:543-554.
PUBMED | CROSSREF

50. Verheyden G, Nieuwboer A, De Wit L, Feys H, Schuback B, Baert I, Jenni W, Schupp W, Thijs V, De Weerdt W. Trunk performance after stroke: an eye catching predictor of functional outcome. J Neurol Neurosurg Psychiatry 2007;78:694-698.
PUBMED | CROSSREF

51. Kim TL, Hwang SH, Lee WJ, Hwang JW, Cho I, Kim EH, Lee JA, Choi Y, Park JH, Shin JH. The Korean version of the Fugl-Meyer Assessment: reliability and validity evaluation. Ann Rehabil Med 2021;45:83-98.
PUBMED | CROSSREF

52. Jung HY, Park JH, Shim JJ, Kim MJ, Hwang MR, Kim SH. Reliability test of Korean version of Berg Balance Scale. J Korean Acad Rehabil Med 2006;30:611-618.

53. Seo HD, Kim NJ, Chung YJ. Reliability of the Korean version of the trunk impairment scale in patients with stroke. J Korean Acad Univ Trained Phys Ther 2008;15:87-96.