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Validity, reliability and minimum detectable change of the maximum step length test in people with stroke

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ABSTRACT

Stroke is a significant cause of deficits in balance, mobility and disability. Although tests of stepping speed are associated with balance performance after stroke, relationships between clinical tests of stepping distance and balance performance have not been investigated in people with stroke. A validated test of stepping distance and balance in older adults (the maximum step length [MSL] test), and two clinical measures associated with balance in people with stroke (the five-times-sit-to-stand test [FTSST] and gait speed) were evaluated in nineteen independent community-dwelling people with chronic stroke. There were strong relationships between MSL and performance on the clinical balance measures (Pearson's r 0.69 to −0.88), suggesting that MSL is a valid measure of balance after stroke. Test–retest reliability coefficients were excellent for the MSL tests (ICC both limbs; 0.98). Standard error of measurement expressed as a percentage of mean MSL was computed as 5.6% (hemiparetic leg) and 5.4% (unaffected leg), indicative of low levels of measurement error and excellent absolute reliability of the MSL test in people with stroke. Minimum detectable change expressed as a percentage of mean MSL was low (14.9% to 15.4%), suggesting that MSL may be sensitive to detecting change in physical performance in people with stroke. Advantages of the MSL test are that it is easy to administer, requiring minimal training, equipment, time or space. These advantages, together with the validity of the MSL test, its excellent test–retest and absolute reliability, and its low minimum change percent value suggest that MSL may be a useful measure of balance capabilities in people with stroke.

1. Introduction

Stroke is a significant cause of deficits in balance, mobility [1–3] and disability [4–6] and is associated with falls during the acute as well as chronic stages of recovery [7]. The reported incidence of falls in people with stroke varies among studies, ranging from 14% to 73% of survivors [7]. In order to optimize motor recovery, maximize functional capabilities and reduce risk for falls in people with stroke, a major focus of rehabilitation efforts after stroke is devoted to improving balance performance.

Clinicians require reliable and valid clinical balance tests to identify balance deficits in people with stroke, as well as to evaluate response to rehabilitation interventions designed to improve balance after stroke. An assessment tool which is widely-used in balance studies after stroke is the Berg Balance Scale [8,9]. A recent systematic review of the utility of the BBS in rehabilitation after stroke indicated that although the BBS may be a valid measure of balance performance after stroke, scores on the BBS are not predictive of falls after stroke [9]. Furthermore, floor and ceiling effects of the scale limit its usefulness when assessing patients with severe or mild impairments, prompting the suggestion that clinicians use other balance tests in conjunction with the BBS when assessing balance after stroke [9]. Because of limitations such as these in current tools used to assess balance after stroke, there is a need to develop and test new balance tests. Although a number of studies indicate that poor performance on clinical tests of stepping speed [10–12] and distance [10,11,13] are associated with impaired performance on balance tests in older adults, few clinical tests of stepping performance have been investigated in relation to balance in people with stroke. Clinical stepping tests which have been associated with balance performance in people with stroke are tests of stepping speed such as the step test [14], and the four-square-step-test (FSST) [15]. In contrast to tests of stepping speed, relationships between clinical tests of stepping distance and balance have not been investigated in people with stroke. The validity of tests of stepping performance used in studies of balance in older adults warrants investigation in people with stroke.

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The maximum step length (MSL) test is a clinical test of stepping distance in which participants step forward as far as possible with one leg, before returning to the starting position [10,11]. Balance-impaired older adults perform significantly poorer on the MSL test than unimpaired older adults [11], and MSL values correlate significantly with clinical measures of balance in community-dwelling older adults [10,11,13]. These studies provide strong evidence that the MSL test is a valid measure of balance performance in older adults. The advantages of the MSL test are that it is easy to administer and requires minimal training, equipment, time or space. Because of the validity of the MSL test in older adults, combined with the high incidence of falls in people with stroke, we conducted a study with the primary objective of investigating the validity of the MSL test as a measure of balance in people with stroke. To the best of our knowledge the MSL test has not been investigated in relation to balance performance in people with stroke. We hypothesized that poorer performance on the MSL test would be associated with impaired performance on two clinical tests–the five-times-sit-to-stand test (FTSST) and gait speed–associated with balance performance in people with stroke [16,17]. These measures of balance performance were chosen as sit to stand and ambulation represents functional activities which may be functional goals and a strong focus of rehabilitation for many stroke survivors. Secondary objectives were to quantify the relative and absolute reliability, as well as the minimum detectable change at the 95% confidence level (MDC_{95}) for the MSL test, the FTSST and for 10-meter gait speed in people with stroke. MDC is the amount of change in a measure exceeding chance variability and random measurement errors [18] and in studies of clinical populations it represents the smallest amount of change in a measure that is considered a real change in performance [19].

2. Materials and methods

2.1. Participants

Individuals who were at least 18 years of age, had a history of a single stroke not less than 4 months prior to enrollment in the study and who were able to ambulate without physical assistance with or without an assistive device, were eligible to be included in the study. Participants were recruited from an outpatient rehabilitation clinic at the Rehabilitation Institute of Michigan and from the Spice of Life Stroke Club. A screening medical history was elicited to determine eligibility to participate in the study. Exclusionary criteria included significant cognitive deficits, pregnancy, and any condition that would affect the participant's ability to ambulate and transfer independently (e.g., history of other neurological condition such as Parkinson's disease, fractures, amputations, and severe arthritis). Cognitive ability was assessed by using the Short Orientation Memory Concentration Test [20]. Participants provided a self-report rating of their health (poor; fair; good; very good; excellent), as well as the amount of exercise or physical activity per week (more than 30 min 3 times per week; 5–30 min 3 times per week; sedentary). The study protocol was approved by the institutional review boards of Wayne State University and the Detroit Medical Center. All participants provided written informed consent to participate in the study.

2.2. Maximum step length

Participants stood with feet together and arms crossed over the chest. They stepped out maximally maintaining the stance leg in the starting position, and were required to return safely to the starting position with no loss of balance. Participants were safeguarded by stand-by assistance of testers positioned on both sides. Attempts were not recorded if the participant lost balance during stepping, changed position of the stance leg, or could not return to the starting position in one continuous step. A standard tape measure adhered to the floor was used to record distance stepped. Each lower extremity was tested three times within the same testing session following one practice trial, and mean MSL was recorded for each leg. In older adults MSL exhibits excellent reliability when tested at a single session (ICC 0.96) or at sessions 30 days apart (ICC 0.90) [13]. The MSL test is significantly associated with clinical measures of balance [10,11,13] and exhibits good sensitivity (70%) and specificity (69%) in predicting falls in older adults [21].

2.3. Five-times-sit-to-stand test

From the seated position with arms crossed over the chest and back against the chair, participants were timed as they performed five sit-to-stand transfers as quickly and safely as possible. Attempts were not recorded if the participant failed to come to a full standing position during each transfer. Participants did not use assistive devices during testing. A standard height chair with no armrests was used throughout all trials. Each participant was tested three times within the same testing session following one practice trial, and mean FTSST time was recorded. Reliability of the FTSST after stroke is excellent (ICC 0.99) [22], and the FTSST is associated with performance on the Berg Balance Scale (BBS) ($r = -0.837$; $p<0.01$) in hemiparetic subjects [16], suggesting that FTSST is a valid measure of balance performance in people with stroke.

2.4. Gait speed

Gait speed was measured over the middle 10 m of a 14-meter walk by using a standard stopwatch. Two additional meters prior to and after the timed 10 m were included [23] to account for acceleration and deceleration, thereby ensuring that gait speed was assessed during steady state ambulation. Participants were instructed to walk at a comfortable pace and were permitted to use a walking device during the testing of gait speed. Timing began as the front of the foot crossed the starting line (2-meter mark) and stopped when the front of the foot crossed the finish line (12-meter mark). Gait speed was computed by dividing distance walked (10 m) by the number of seconds to complete the 10-meter walk, and was recorded as meters/second. Each participant was tested three times within the same testing session following one practice trial, and mean gait speed was recorded. The reliability of 10-meter gait speed after stroke is excellent (ICC 0.94) [24]. In people with chronic stroke, gait speed exhibits a strong association with balance performance assessed as the BBS ($r = 0.74$; $p<0.01$) [17], suggesting validity of gait speed as a measure of balance capabilities after stroke.

2.5. Statistical analysis

As the outcome measures of MSL, FTSST and gait speed all conformed to a normal distribution (Kolmogorov–Smirnov test $p>0.05$), parametric statistical procedures were employed in this study. The difference in the MSL between the hemiparetic and unaffected limbs was evaluated with a paired *t*-test. Strength of relationships among variables was quantified by using the Pearson's correlation coefficient (Pearson's *r*). Test–retest reliability of MSL, FTSST and gait speed were computed by using $ICC_{2,1}$ [25], which represents an estimate of relative reliability of the 3 measures. The standard error of measurement (SEM) which quantifies measurement errors in the same units as the original measures [26,27], was computed as an estimate of absolute reliability of MSL, FTSST and gait speed. The SEM was computed as $SD \times \sqrt{(1-r)}$, where SD was the standard deviation and *r* was $ICC_{2,1}$ which is the test–retest reliability coefficient of each variable. The SEM was used to compute MSL, FTSST and gait speed MDC_{95} values, which represent the thresholds for real change in physical performance at the 95% confidence level. The MDC_{95} values were computed as $Z \times SEM \times \sqrt{2}$, where $Z = 1.96$, the score associated with the 95% confidence level and $\sqrt{2}$ is a