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Development of a Qualitative Evaluation Tool for Stand to Sit

Hyun-Sung Kim[1], Young-Jun Shin[1], Seong-Gil Kim[2*]

[1]Department of Physical Therapy, Kyungwoon University, Gumi 39160, Korea

[2]Department of Physical Therapy, Sun Moon University, Chungnam 31460, Republic of Korea

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Abstract

Introduction: Many studies have evaluated various tests and instruments to identify methods appropriate for the assessment of balance in stroke patients. But, movement quality tends to be quantitatively evaluated, due to limitations associated with qualitative evaluations.

Objectives: This study aimed to perform an equipment-based objective assessment of StandTS performance in stroke patients to develop the stand to sit test (SST).

Methods: In this cross-sectional study involving 61 stroke patients meeting inclusion criteria, data on sex, age, height, weight, affected side, and onset duration were collected through patient interviews and medical records. Participants underwent tests like FTSST, FRT, TUGT, and BBS, with seat pressure data measured during FTSST using a device from X Sensor Technology Corporation, Canada. The Seat Pressure Sensing Test (SST) was developed based on this data, with reliability and validity measures to validate its use in assessing post-stroke patients' balance and postural control.

Results: Regarding the validity of the SST, SST scores were positively correlated TUGT scores ($r = 0.342$, $p < 0.01$) and negatively correlated with FTSST ($r = -0.056$, $p > 0.05$), FRT ($r = -0.824$, $p < 0.01$), and BBS ($r = -0.386$, $p < 0.01$). The FTSST was positively correlated with the TUGT ($r = 0.054$, $p > 0.05$), and negatively correlated with the FRT ($r = -0.031$, $p > 0.05$) and BBS ($r = -0.093$, $p > 0.05$). The FRT was positively correlated with the BBS ($r = 0.423$, $p < 0.01$) and negatively correlated with the TUGT ($r = -0.259$, $p < 0.05$). Finally, the TUGT was negatively correlated with the BBS ($r = -0.793$, $p < 0.01$)

Conclusions: In particular, the test may facilitate the qualitative assessment of balance and postural control in person's post-stroke receiving inpatient care.

Keywords: stroke; stand to sit; qualitative evaluation tool

1. Introduction

Stroke is a disease caused by the disruption of the blood flow to the brain as a result of cerebrovascular anomalies. Incomplete recovery occurs in approximately 73% of stroke patients. Although symptoms vary depending on the site of lesion, physical functional impairments such as ipsilateral hemiplegia, loss of isolated movements, and somatosensory system abnormalities usually occur [1]. Particularly, stroke patients display a loss of selective movement and coordination impairment due motor pattern abnormalities and muscle tension, characteristics that limit their ability to maintain postural control [2].

Many studies have evaluated various tests and instruments to identify methods appropriate for the assessment of balance in stroke patients. Some of the most widely used tests include the five times sit to stand test (FTSST), functional reach test (FRT), timed up and go test (TUGT), and the Berg balance scale (BBS) [3]. However, outcomes of existing tests differ based on patient age, major diseases, and the severity of physical disability. As a result, the generalizability of results is limited [4]. Particularly, though tests are convenient and simple, they are utilized by people. Therefore, tests are more vulnerable to non-systematic errors than are device-based measurements [5]. Further, movement quality tends to be quantitatively evaluated, due to limitations associated with qualitative evaluations.

The FTSST involves the measurement of the time needed to perform five sit to stand (SitTS) and stand to sit (StandTS) repetitions. Past studies have analysed motion using various types of equipment to enhance the reliability and validity of the test. One method for performing such an analysis is the attachment of an inertial measurement unit (IMU) around the waist, attaching a tracking point on the head, using kinetic sensors [6], and at-taching a gyroscope on the sternum [7]. These studies established the reliability and valid-ity of the test via spatiotemporal analyses of motion. Further, FTSST movement can classified as either SitTS or StandTS based on the type of movement performed. While the two may seem similar, they differ based on the type of physical control, lower limb strength, and balance required when the center of gravity and center of mass shifts [8]. However, analyses of motions of the StandTS portion of FTSST are relatively lacking compared to those of the SitTS portion [9].

StandTS is the most basic postural transitional movement performed frequently throughout activities of daily living (ADL), and is performed > 60 times per day, on aver-age. Although it can be mistaken as a simple motion, good physical control, high muscle performance, coordination, and balance are needed to perform the motion stably. When compared with other ADL such as ambulation, StandTS requires greater lower limb joint torque and range of motion (ROM) [10]. Stroke patients not only display asymmetrical muscle activity during StandTS due to abnormal coordination and muscle weakness but also suffer from excessive shock due to a lack of effective eccentric contraction to ensure the velocity of the body decreases as it descends. This ultimately strains the spine, and momentary instability due to shock increases risk of falls [11].

Therefore, the aim of this study was to perform an equipment-based objective assessment of StandTS performance in stroke patients to develop an instrument that may be used to qualitatively evaluate performance and identify new balance and postural control evaluation criteria. To this end, we will measure seat pressure during the StandTS portion of the FTSST using a pressure measurement device to facilitate the development of a stand to sit test (SST) based on the pressure map created.

2. Materials and Methods

2.1 Participants

Patients with stroke who were hospitalized at Namsan hospital in Daegu were con-sidered for enrollment. The following inclusion criteria were applied: diagnosed with stroke within < 6 months, a Mini-Mental State Examination-Korean version (MMSE-K) score of 24 or higher, lack of orthopedic disease of the lower extremities, and capable of independently performing a SitTS test. The sample size was determined using G*Power 3.1.7 software. For a two-tailed logistic regression with a significance level (α) of .05, power (1-β) of .80, odds ratio (OR; large effect size) of 2.5, and probability H0 of 0.3 the appropri-ate sample size was set to 59. We enrolled 61 patients. Written informed consent was ob-tained from each participant prior to study inclusion, and all aspects of the study were conducted in accordance with the principles stipulated in the Declaration of Helsinki. The ethics committee of the Daegu University Institutional Review Board approved the study (approval number: 1040621-201903-HR-027-02).

2.2 Study Procedure

This was a cross-sectional study. From patient interviews and the medical records of 61 stroke patients who meet inclusion criteria, the following information was collected: sex, age, height, weight, affected side, and onset duration. Participants performed FTSST, FRT, TUGT, and BBS. To develop the SST, we measured seat pressure during the FTSST using a pressure measurement device (XSensor Technology Corporation, Canada).

To perform measurements needed to develop SST, patients were asked to sit on a pressure measurement device that was placed on a height-adjustable Bobath table (Nteck, Korea). To generalize measurements, we adjusted the height of the table and position of the patient’s feet such that the hip joint, knee joint, and ankle joint formed a 90º angle (Figure 1).

For baseline value collection, each patient sat on the equipment for 1 minute at rest. While patients performed the FTSST, seat pressure during the StandTS portion of the test was measured in real time. The FTSST was performed twice(trial 1 and trial 2), with a one-minute rest period between tests to prevent fatigue. The SST was developed based on seat pressure data, and absolute reliability, relative reliability, and concurrent validity values were determined to validate the test (Figure 2).

Figure 1

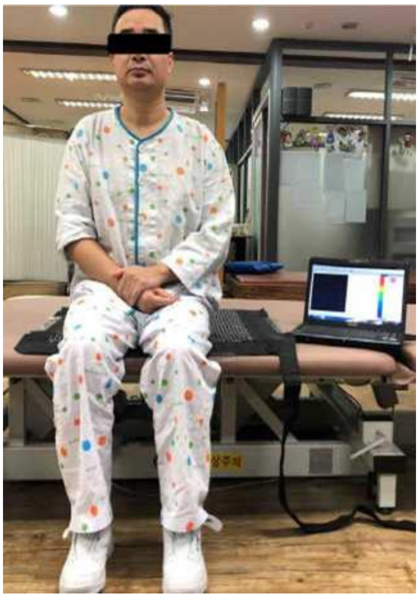

Fig. 1. The posture adopted during stand to sit test measurement acquisition is shown

Figure 2

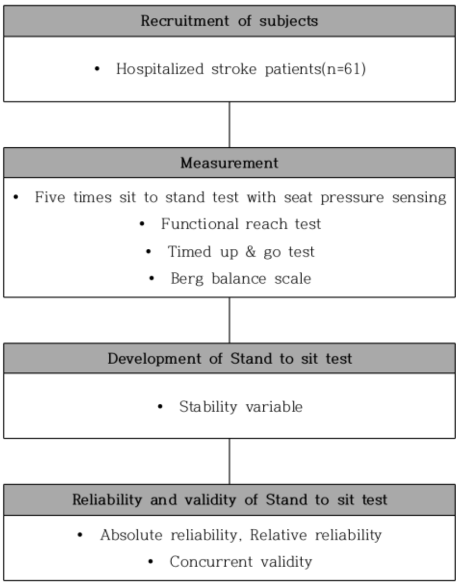

Fig. 2. Study flow chart

2.3 Outcome measures

2.3.1 Existing Tests

The FTSST measures the time needed to move from a sitting to standing position five times. In the test, the duration from when the hip first lifts from the table to the moment the hip touches the table after the fifth repetition is recorded. The patient is told to move as quickly as possible. To prevent compensation by the upper body, patients were asked to stand only using their lower limb strength, while holding their affected hand with their non-affected hand. Test-retest reliability (intra-class correlation coefficient; ICC) was previously determined to be 0.95 [12].

For the FRT, the participants were asked to stand with their feet shoulder-width apart, raise their non-affected arm to the acromion, and extend the arm parallel to a measure-ment tape that hung on the wall. The participants were then asked to make a tight fist, and the distance from one most-protruded distal end of the third metacarpal to the other was measured. In the test, the distance from the point at which a patient's arm is extended while standing comfortably to the farthest point they can reach. When participants are reaching, the feet must remain grounded. The test-retest reliability (ICC) of the FRT is 0.92 [13].

The TUGT is a means to rapidly assess basic mobility, balance, and gait. The time needed to rise from a chair with a backrest, walk 3 meters, and return to the chair and sit is measured. Tasks are performed in the following order: SitTS, walk 3 m, turn around, walk back 3 m, turn around, and StandTS. The inter-rater reliability (r) of this test is 0.99 [14].

The BBS is a 14-item scale used to predict fall risk in older adults by assessing balance and mobility. Components of the test are as follows: sitting to standing, standing unsupported, sitting unsupported, standing to sitting, transfers, standing unsupported with eyes closed, standing unsupported with feet together, reaching forward while stand-ing, retrieving object from floor, turning left and right, turning 360°, placing a foot on a stool, standing with one foot in front, and standing on one foot. Each item is given a score from 0–4. The maximum test score of 56, with higher scores indicating better balance. The test-retest reliability (ICC) of the BBS is 0.98, and its inter-rater reliability (r) is 0.96 [15].

2.3.2 Stand to Sit Test

To develop the SST, seat pressure during the FTSST was measured using an XSEN-SOR (XSensor Technology Corp., Canada) device. The device consists of a 78.74 cm × 78.74 cm pad with a sensing area of 60.96 cm × 60.96 cm, and 2,304 sensing points. The area of a single sensor is 1.27 cm x 1.27 cm, with sensors positioned in a 48 × 48 design. The range of detectable pressure for the test was 5–256 mmHg. We used X3 Medical v.5 soft-ware to operate the device, which allowed researchers to graphically visualize pressure changes and distributions of pressure collected via pressure sensors according to time or frame. Average pressure was calculated using these data.

Resting seat pressure was measured for 1 minute and was defined as Preference val-ue. Maximum values of sum of left and right seat pressure during each of the five sequen-tial StandTS reps were defined as P1, P2, P3, P4, and P5, respectively (Figure 3).

Figure 3

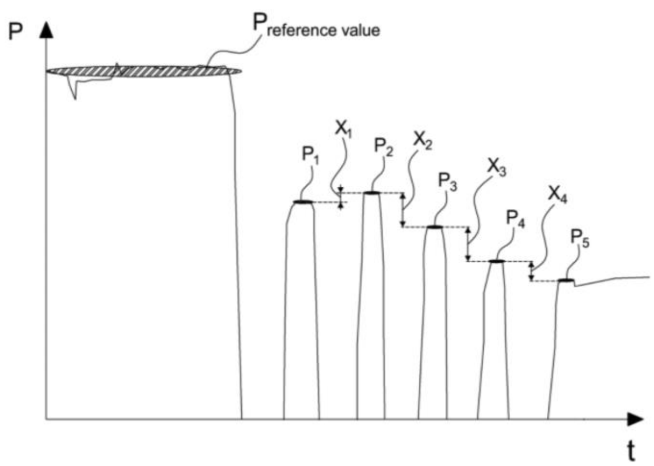

Fig. 3. Seat pressure measured during the stand to sit test.

The formula for SST is as follows:

[(P1 + P2 + P3 + P4 + P5)/5]/P(Reference value) ×100, Where P1–5 indicate maximum seat pressure values determined during the FTSST, and Preference value indicates resting seat pressure. The SST was defined as the ratio of average maximum seat pressure values determined during the FTSST versus the Preference value, where smaller values indicate motion of increased stability.

2.4 Statistical Analysis

The general characteristics of participants were analyzed using descriptive statistics. The reliability of the SST was assessed by determining absolute and relative reliability. Absolute reliability was analyzed using standard error of measurement (SEM) and minimal detectable range (MDC). Relative reliability was analyzed with ICC. The validity of the SST was tested using concurrent validity in relation to the existing tools FTSST, FRT, TUGT, and BBS based on Pearson correlation coefficients. Statistical analyses were per-formed using the SPSS ver. 20.0 for Windows (IBM Corp., USA), and statistical significance (α) was set at 0.05.

3. Results

The general characteristics of participants including sex, age, and duration since disease onset are shown in Table 1. Regarding the reliability of the SST, the mean values determined for the first and second repetitions of the test were 89.693 ± 6.694 and 88.093 ± 6.623, respectively. The mean score for both repetitions was 88.893 ± 6.679. Reliability in-dices were as follows: ICC, 0.618 (0.369∼0.769); SEM, 2.557; and MDC 10.023 (Table 2) (Figure 4).

Table 1. General characteristics of subjects (n=61)

Characteristics	Values
Sex: male/female, n (%)	35 (57.4)/26 (42.6)
Age (y)	55.48 ± 7.48
Height (cm)	162 ± 8.2
Weight (kg)	62.3 ± 12.5
Affected side: right/left, n (%)	39 (63.9)/22 (36.1)
Onset duration (months)	3.83 ± 1.18

Table 2. Reliability of the Stand to sit test

	Mean ± SD		Mean ± SD of 2 trials	ICC (95% CI)	SEM	MDC
	Trial 1	Trial 2				
SST (mmHg)	89.693 ± 6.694	88.093 ± 6.623	88.893 ± 6.679	0.618 (0.369–0.769)	2.557	10.023

SST, stand to sit test; SD, standard deviation; ICC, intra-class correlation coefficient; CI, confidence interval; SEM, standard error of measurement; MDC, minimal detectable change

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Figure 4

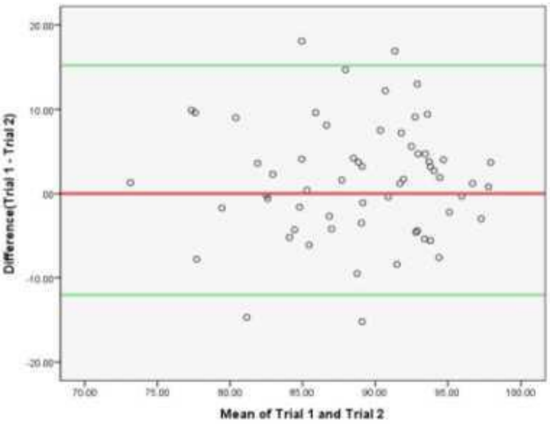

Fig. 4. Bland-Altman method for plotting differences in scores against the mean values of the stand to sit test. Green lines define upper and lower limits of agreement (mean difference of ± 1.96 × SD).

Regarding the validity of the SST, SST scores were positively correlated TUGT scores (r = 0.342, $p < 0.01$) and negatively correlated with FTSST (r = -0.056, $p > 0.05$), FRT (r = -0.824, $p < 0.01$), and BBS (r = -0.386, $p < 0.01$). The FTSST was positively correlated with the TUGT (r = 0.054, $p > 0.05$), and negatively correlated with the FRT (r = -0.031, $p > 0.05$) and BBS (r = -0.093, $p > 0.05$). The FRT was positively correlated with the BBS (r = 0.423, $p < 0.01$) and negatively correlated with the TUGT (r = -0.259, $p < 0.05$). Finally, the TUGT was negatively correlated with the BBS (r = -0.793, $p < 0.01$) (Table 3) (Figure 5).

Table 3. Comparison of FTSST, FRT, TUGT, and BBS validities with that of the SST

		FTSST (s)	FRT (cm)	TUGT (s)	BBS (score)
		17.035 ± 2.165	15.355 ± 2.664	25.740 ± 4.504	27.065 ± 4.369
SST (mmHg)	88.893 ± 6.679	-0.056	-0.824**	0.342**	-0.386**

SST, stand to sit test; FTSST, five times sit to stand test; FRT, functional reach test; TUGT, timed up & go test; BBS, Berg balance scale. $^{*}p < 0.05$, $^{**}p < 0.01$.

Figure 5

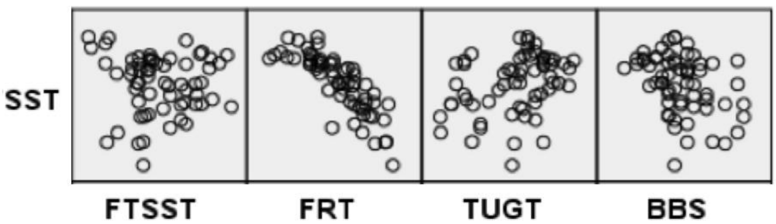

Fig.5. Correlations between evaluation tool values

4. Discussion

The aim of this study was to develop and evaluate the absolute, relative and concur-rent reliability of a tool that may be used to evaluate balance and postural control based on StandTS movement, during which stroke patients are at increased risk for falls. To this end, we measured seat pressure during the StandTS portion of the FTSST to successfully develop an SST. To evaluate the reliability of the SST, ICC, SEM, and MDC were deter-mined.

The ICC of the SST was determined to be 0.618, indicating a moderate reliability. For the same test, SEM was 2.557, a value < 8.8 (10% of average value for the test, 88.893). Thus, error was considered acceptable. MDC for the SST was 10.023, a value < 19.59 (20% of maximum the value measured, 97.950), and thus, was considered acceptable. MDC values also reflect the degree to which functional changes may be predicted; therefore, they may be important for use in clinical decision making [16].

Regarding safety parameters, the mean stability score dropped by 10.023, from 88.893 to 78.870. These findings suggest that postural control can be improved by more than 11.28%. It has been shown that stroke patients undergo spontaneous recovery throughout the three months that follow disease onset, and the most substantial portion of motor function recovery via rehabilitation occurs throughout the six months that follow disease onset [17]. Study participants were in acute or subacute stages of stroke, with < 6 mos from disease onset. Therefore, postural control limitations due to differing durations of functional recovery experienced in the study group presumably contributed to the moderate reliability observed. In addition, the high absolute reliability of the SST may have been observed because the test qualitatively evaluates motion during StandTS using pressure measurement devices.

The concurrent validity of SST was analysed using Pearson correlation coefficients, with obtained values classified, as follows: very high correlation, 0.8–1.0; high correlation, 0.6–0.8; relatively high correlation, 0.4–0.6; and moderate correlation 0.2–0.4. The SST correlated highly and negatively with the FRT ($r = -0.824$, $p < 0.01$). Postural control refers to the degree to which one can control ones' own body in a given space. The ankle joint strategy is generally used to maintain postural control [18]. The ankle joint strategy re-quires appropriate ROM and concentric and eccentric muscle activities of the lower limbs. Limitations to functional performance including locomotion are strongly associated with dorsi- and plantar-flexor weakness [19]. A higher FRT score indicates good anterior and posterior control, which is essential for the ankle joint strategy [20]. Good ankle ROM and ankle joint strategy performance were influenced by lower limb muscle activities, likely affecting postural control during the StandTS movement. This resulted in an increase in FRT scores and a decrease in SST scores.

Further, SST scores were low correlated with TUGT ($r = 0.342$, $p < 0.01$) and BBS ($r = -0.386$, $p < 0.01$) scores. TUGT and BBS include various movement in addition to StandTS, which likely weakened correlations observed when TUGT and BBS scores were compared with the SST. The FTSST was not significantly correlated with the SST ($r = -0.056$, $p > 0.05$). Since lower limb weakness is a major problem in stroke patients, the ability of patients to perform SitTS and StandTS movements is limited. Further, stroke heavily influences balance, which is required to perform the FTSST. The test has previously been shown to be a useful tool for assessing lower limb strength and balance in stroke patients [21]. However, because patients are instructed to perform the FTSST as quickly as possible [22], patients moving rapidly, making the test less ideal for evaluating qualitative parameters including physical control.

This study has a few limitations. First, findings have limited generalizability due to the small sample size of the study. Subsequent studies should recruit more patients with more diverse diseases. Second, the SST requires use of a pressure measurement device, which limits the feasibility of the test in some settings. Subsequent studies should develop a simpler version of the SST. Third, the maximum detectable pressure of the device used in this study was 265 mmHg; therefore, the measurement of peak pressure upon sitting during StandTS was limited. Hence, average pressure measured along with data from other appropriate variables should be assessed via the measurement of peak pressure and con-tact area. In addition, the reliability and validity of the SST should be tested using a force plate and an IMU as well as pressure measurement device during StandTS movements. Fourth, the majority of participants included in the study were older adults, so it is difficult to minimize the potential of comorbidities to impact balance and postural control.

5. Conclusion

The patient's balance and postural control ability are required to perform a stable stand to sit [23]. We developed an SST based on the seat pressure data taken during the FTSST and evaluated motion stability during StandTS.

In summary, in five times sit to stand, we tried to evaluate the quality of the motion based on the amount of change in the seat pressrue value, which is quantitative data measured during the five repetitions of stand to sit motion. If the measured seat pressure value was constant, it was interpreted that the motion was performed stably, so postural control and balance were interpreted as normal, and if the measured seat pressure value was not constant, postural control and balance were interpreted as atypical. Since the test was determined to have high reliability and validity, findings have the potential to be useful clinically. In particular, the test may facilitate the qualitative assessment of balance and postural control in person's post-stroke receiving inpatient care.

Author Contributions: Conceptualization, H.-S.k.; methodology, H.-S.k.; software, Y.-J.S.; formal analysis, S.-G.k.; investigation, Y.-J.S.; resources, S.-G.k.; data curation, S.-G.k.; writing—original draft preparation, H.-S.k.; writing—review and editing, Y.-J.S.; visualization, S.-G.k.; supervision, H.-S.k.; project administration, S.-G.k.; funding acquisition, H.-S.k. All authors have read and agreed to the published version of the manuscript.

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board of Daegu University (1040621-201903-HR-027-02).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study. Written informed consent has been obtained to publish this paper.

Data Availability Statement: The data used to support the findings of this study are available from the corresponding author upon reasonable request.

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Conflicts of Interest: The authors declare no conflict of interest.

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