Original Article

A modified seated side tapping test in which the arms are crossed also reflects gait function in community-dwelling elderly

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Abstract. [Purpose] Seated side tapping test (SST) performance is associated with mobility impairment in the elderly. Although this test was developed to assess trunk function, interpretation of its results may be confounded by the upper-limb movements in its protocol. Here, this study aimed to validate the association between trunk function and gait function by means of the Arms Crossed SST (AC-SST), a modified version of the SST in which the arms are crossed over the chest, to exclude the effects of the upper limbs. [Subjects and Methods] A total of 116 community-dwelling elderly people were enrolled in the study (mean age: 75.1 ± 5.5 yrs). Measurement categories were gait function (gait speed and TUG), lower extremity strength (knee extension and flexion strength), trunk muscle endurance (trunk extension and flexion endurance), and trunk function (SST and AC-SST). [Results] AC-SST performance significantly correlated with gait function items, as did SST performance. Moreover, AC-SST was one of the significant predictor variables of gait function selected in stepwise multiple regressions. [Conclusion] Gait function associated with performance on the AC-SST, a test of trunk function in which the effects of upper limb function were excluded, reinforcing the importance of trunk function to elderly mobility.

Key words: Seated side tapping test, Gait, Trunk function

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INTRODUCTION

Gait function is a very important ability in the elderly, with recognized relationships with fall risk1, institutionalization2, activities of daily living (ADL) performance3, and even life expectancy4. Measures for objectively evaluating gait function include the gait velocity test and Timed Up and Go test (TUG), which are widely used since their performance is unaffected by culture, language, or education level1 and they have confirmed reproducibility and reliability5. When one considers that most falls happen during walking6, however, performing these tests put elderly people with diminished physical function in danger of falling. Moreover, it is difficult to use these tests to assess the physical performance of immobile patients7.

To overcome these issues, we developed a physical function test performed while seated: the Seated Side Tapping test (SST)8, 9). In this test, the participant sits in a chair with both arms raised to the sides, and alternately taps a marker on their left and on their right, positioned 10 cm from their fingertips, ten times as fast as they can. Test performance is measured in terms of the time required to complete this task. One study on healthy community-dwelling elderly people observed significant moderate correlations of SST with gait velocity (r=−0.43) and TUG (r=0.59); the measure was also found to relate to instrumental ADL (IADL) disability8. Similarly, a study on frail elderly people receiving rehabilitation services at a geriatric health services facility found significant correlations of SST with gait velocity (r=−0.59) and TUG (r=0.63), as well...
as associations with ADL levels and the need for walking aids\textsuperscript{9}. Performed while seated, the test is characterized by high safety and its accommodation of individuals who cannot walk independently.

Several findings led us to develop the SST: trunk function is important for balance preservation and gait function\textsuperscript{6}, medio-lateral trunk sway is associated with greater instability during walking as individuals age\textsuperscript{10, 11}, and the ability to move the limbs quickly is an important factor that affects gait function\textsuperscript{12}. More specifically, we developed the SST as a way to collectively assess the three factors implicated in these findings: trunk function, lateral movement, and movement velocity. However, upper limb function may be a confounding factor in interpreting SST performance, as participants move their arms to tap the markers during the test.

There is obviously a certain relation between upper-limb and lower-limb function: the same principle underlies why many studies employ grip strength as a way of representing whole-body muscle strength\textsuperscript{13}. Moreover, arm swinging during walking improves stability, and this effect is enhanced with age\textsuperscript{14}, and as we showed in a preceding study upper limb movement velocity is significantly associated with gait speed\textsuperscript{15}. Given these findings, we cannot reject the possibility that SST performance reflects upper-limb function, and consequently that this was in some way responsible for the relationships between SST and gait function.

In this study, the gait function of elderly participants was examined with respect to their performance on the Arms Crossed SST (AC-SST), a new SST variant in which the arms are folded across the chest, to clarify the relationship between trunk function and gait function in the elderly under stricter conditions. Observations of significant relationships between AC-SST performance and gait function indicators should reinforce the important role played by trunk function in mobility impairment in the elderly.

**SUBJECTS AND METHODS**

A total of 116 community-dwelling healthy elderly people were analyzed. Participants were recruited via posters displayed in institutions where care prevention services were provided. There were three inclusion criteria: 1) age of 65 years or older, 2) ability to walk independently, and 3) ability to understand directions necessary to complete testing measures. All participants provided written consent after the study purpose and contents were thoroughly explained to them. This study was conducted with the approval of the Committee on Research Ethics of the School of Comprehensive Rehabilitation, Osaka Prefecture University (approval number, 2010-01).

Measurement items were broadly divided into three categories: gait function, muscle strength, and SST performance. Participants underwent all measurements on the same day, with the test order randomized.

Gait function was measured in terms of normal gait speed and TUG. Gait speed was calculated according to the time a participant took to travel the middle 5 m of a 11-m walkway, which they were directed to walk down with the verbal instruction, “Please walk at the speed you always walk”. The TUG was performed according to the method of Podsiadlo et al.\textsuperscript{16} The participant starts in a seated position, leaning against a backrest. Following a cue, they stand up, walk straight ahead along a 3-m line, turn around, and return to the chair to sit. Test performance is measured using a stopwatch, as the time from the cue to when the participant’s back again touches the backrest. Normal gait speed and TUG were both measured twice per participant, with the faster value of each pair used in analysis.

Muscle strength was measured in terms of lower extremity strength\textsuperscript{17} and trunk muscle endurance\textsuperscript{18}, both of which have been shown to be associated with gait function. Lower extremity strength was measured in terms of knee extensor strength and knee flexor strength, using an isokinetic dynamometer (Biodex System3: Biodex medical system) set at an angular velocity of 60\textdegree/s. Each was measured three times, with the maximum value used in analysis. Before measurements, participants warmed up with 3 min of light pedaling using a cycle ergometer with a low load. Trunk muscle endurance was measured in terms of trunk flexor and extensor endurance: these were measured according to the method of Suri et al.\textsuperscript{19} For trunk flexor endurance, the participant sat on a level exam table with their feet on the table, their knees bent at 90\textdegree flexion, and their trunk tilted backward to 30\textdegree from vertical: the time they could maintain this position was measured using a stopwatch. For trunk extensor endurance, the participant stood on a tilt table inclined at 45\textdegree from vertical, with their upper body unsupported: the time they could maintain their hip angle at 0\textdegree was measured. An upper limit of 240 s was adopted for both the trunk flexor and extensor endurance tests.

SST performance was measured using the normal SST and the AC-SST. In the SST, the participant sat upright in a chair (seat height=41 cm) with both arms extended laterally, and the examiner placed one marker on either side, 10 cm from the fingertips of their left and right hands (Fig. 1A). They were verbally instructed to “Please alternately hit the left and right marker 10 times, as fast as you can”, and the time required to complete the task was measured using a stopwatch.

In the AC-SST, the participant sat upright in a chair (seat height=41 cm) with both arms extended laterally, and the examiner placed one marker on either side, 10 cm from the fingertips of their left and right hands. The participant was instructed to “Please walk at the speed you always walk”, and the time required to complete the task was measured using a stopwatch. The limbs were held together with their fingertips at the center of the table. The participant was instructed to “Please alternately hit the left and right marker 10 times, as fast as you can”, and the time required to complete the task was measured using a stopwatch.
The set-up for the AC-SST was similar: the participant sat in a chair (seat height=41 cm) with two foam pads positioned to their sides, 10 cm from the left and right acromion (Fig. 1B). They were verbally instructed to “Please cross your arms in over your chest, then alternately hit with your shoulders the foam pads to your left and right 10 times, as fast as you can”, and the time required to complete the task was measured using a stopwatch. SST’s reproducibility has been confirmed in a previous validation study8).

Statistical analysis consisted of Pearson’s correlation analysis in order to check for relationships of measurement items with gait function. The two gait function items (gait speed, TUG performance) were correlated against age, BMI, the two lower extremity strength items, the two trunk muscle endurance items, and both SST and AC-SST. Stepwise multiple regression analysis to extract factors associated with gait function was also performed. Gait speed and TUG performance were dependent variables; SST and AC-SST performance and other attributes and measures previous research suggested could influence gait function were inserted as independent variables after accounting for multicollinearity. All statistical analyses were conducted using SPSS v.21.0, with a significance level of 5%.

RESULTS

Participant characteristics and test results are shown in Table 1. Participants included 30 men and 86 women, of an average age of 75.1 ± 5.5 yrs.

Correlation analysis results are shown in Table 2. Gait speed and TUG were significantly moderately correlated with both SST and AC-SST. Gait speed was also found to correlate with age, BMI, trunk flexor endurance, and trunk extensor endurance, and TUG with age, trunk flexor endurance, and trunk extensor endurance. In addition, strong significant correlations were observed between SST and AC-SST (r=0.72, p<0.01) and between knee extensor strength and knee flexor strength (r=0.75, p<0.01).

Expected to create multicollinearity problems in the stepwise multiple regression analysis, these relationships were accounted for in two ways: 1) Separate models were run for SST and AC-SST (Model 1 and 2, respectively); 2) Only knee extensor strength, which a previous study found to associated with gait function, was inserted as a representative indicator of knee muscle strength19). Stepwise multiple regression analyses were run with either gait speed or TUG as the dependent variable, and age, gender, BMI, knee extensor strength, trunk flexor endurance, trunk extensor endurance, and SST (Model 1) or AC-SST (Model 2) inserted as independent variables. The significant predictors of gait speed selected in analysis were age, SST, and BMI (Model 1) and age, AC-SST, and BMI (Model 2) (Table 3). The significant predictors of TUG were SST, age, trunk flexor endurance, and gender (Model 1), and age, AC-SST, and trunk flexor endurance (Model 2) (Table 4).
DISCUSSION

SST performance is already known to relate to mobility impairment in the elderly⁶, ⁹). In this study, we investigated whether similar associations would be observed between mobility impairment and performance on the AC-SST, a version of the SST modified to exclude upper limb involvement and better isolate trunk function. Similar to the SST, significant moderate correlations were observed for AC-SST performance with gait speed and TUG. Both SST and AC-SST were selected as significant predictors of gait function in a multiple linear regression analysis, along with other factors considered to contribute to mobility impairment in the elderly: age⁴), gender²⁰), BMI²¹), lower extremity strength¹⁹), and trunk muscle endurance¹⁸). These results suggest that trunk function plays a very important role in elderly mobility, even when the effects of the upper limbs are excluded.

The SST measures a person’s ability to quickly move their trunk from side to side, but it involves upper limb function because the participants must use their arms to tap the markers to their sides. Previous findings have identified the importance of upper limb function to walking: arm movement during walking affects gait stability and trunk motion²², ²³), and arm movement velocity when a person moves their arms as fast as they can relates to gait speed¹⁵). Taken together, these findings indicate that SST performance may reflect upper limb function to some extent, suggesting that the latter mediates the relationship between SST performance and gait function. However, the present study observed AC-SST and SST to be significantly and strongly correlated, and to have roughly equivalent contributions to gait function items in the multiple regression analysis. Based on these findings, it seems unreasonable to conclude that upper limb function somehow mediates the relationship between SST performance and gait function: instead, it seems that not only AC-SST, but also SST primarily reflect trunk function, not upper limb function.

Next, we consider the implications of how an individual moves their center of gravity during gait. We previously compared elderly individuals’ performance on the SST with that on a seated lateral functional reach test. Our results showed that an elderly person’s gait speed is more affected by their ability to quickly move their center of gravity than by the distance they could reach (i.e., the range over which they could move their center of gravity)²⁴). We also compared their performance on the SST, which involves repeated horizontal center-of-gravity movements, with that on the seated anterior-posterior tapping test (APT). Findings showed comparable associations with mobility impairment in the elderly, indicating that mobility impairment does not manifest differently in different direction of movement²⁵). Considering these findings in light of our new observation that SST performance is an important indicator of walking function in the elderly, it seems that the extent of an elderly individual’s mobility impairment is greatly predicted by their ability to quickly shift their center of gravity as they move their trunk while seated, independent of the direction of movement and independent of upper limb involvement in the test. We have previously shown that an elderly person’s gait speed is highly predicted by the speed at which the center of pressure moves through their midfoot during the stance phase of walking²⁶). This demonstrates that the stance phase of walking requires not only stability but also the ability to quickly move one’s center of gravity within the supporting leg. Significant correlations between the SST and AC-SST were likely a result of the involvement of the quick shifting of the individuals’ center of gravity (a trait shared with walking), suggesting the importance of movement velocity of center of gravity in mobility function.

We acknowledge a few potential limitations of this study. First, the pads placed to the left and right of participants in the AC-SST were made of a soft, sponge-like material so that they could not use rebound force when changing direction. However, as this force could not be complete eliminated, we cannot completely ignore the possibility that our results were

| Independent variables | Model 1 | | Model 2 | |
|-----------------------|---------|--------|---------|--------|
| SST                   | B       | SE     | β       | p      |
|                       | 0.476   | 0.120  | 0.334   | 0.000  |
| Age                   | 0.063   | 0.021  | 0.264   | 0.003  |
| Trunk flexor endurance| -0.004  | 0.001  | -0.218  | 0.005  |
| Gender                | -0.545  | 0.220  | -0.188  | 0.015  |

adjusted R²=0.476

| Independent variables | Model 1 | | Model 2 | |
|-----------------------|---------|--------|---------|--------|
| SST                   | B       | SE     | β       | p      |
|                       | -0.063  | 0.020  | -0.297  | 0.002  |
| Age                   | -0.011  | 0.003  | -0.317  | 0.001  |
| BMI                   | -0.015  | 0.006  | -0.211  | 0.011  |

adjusted R²=0.313

Table 3. Results of stepwise multiple regression analysis with gait speed as the dependent variable

Table 4. Results of stepwise multiple regression analysis with TUG as the dependent variable

| Independent variables | Model 1 | | Model 2 | |
|-----------------------|---------|--------|---------|--------|
| SST                   | B       | SE     | β       | p      |
|                       | 0.084   | 0.019  | 0.352   | 0.000  |
| Age                   | 0.063   | 0.021  | 0.264   | 0.003  |
| Trunk flexor endurance| -0.005  | 0.001  | -0.240  | 0.002  |

adjusted R²=0.470

TUG: Timed Up and Go test; SST: Seated Side Tapping test; AC-SST: Arm Crossed Seated Side Tapping test
slightly affected by slight rebound. The fact that gender was not taken into consideration is another potential limitation. Gender differences in mobility impairment in the elderly have been found\(^9\); we cannot reject the possibility of gender differences being present in this study as well.

In conclusion, physical function can be performed very safely using the SST because the participants are seated during measurements. Moreover, it has a simple set-up, and we can perform it with only a stopwatch and three normal chairs: i.e., by using two chairs instead of the two markers and stands used here\(^9\). The SST does not require special measurement techniques, nor are its directions difficult for participants to understand. Furthermore, this testing method is highly versatile, since the task can be completed in a short amount of time, even accounting for preparation time. However, it was difficult to use the test to assess individuals with upper-limb function, such as shoulder periarthritis and hemiplegia. The AC-SST used in this study, in contrast, does not require movement of the arms, and its application can therefore be extended to individuals with upper-limb functional impairment. This novel evaluation method was shown to have high utility for assessing trunk function and gait function.

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