

The Reliability of the Sensory Organization Test in Parkinson's Disease to Identify Fall Risk

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To cite this article:

Joanne DiFrancisco-Donoghue, Min-Kyung Jung, Theresa Apoznanski, William G. Werner, Sheldon Yao. The Reliability of the Sensory Organization Test in Parkinson's Disease to Identify Fall Risk. *International Journal of Neurologic Physical Therapy*.

Vol. 2, No. 5, 2016, pp. 39-43. doi: 10.11648/j.ijnpt.20160205.11

Received: February 13, 2017; **Accepted:** February 25, 2017; **Published:** March 14, 2017

Abstract: The Sensory Organization Test (SOT) is an objective computer-based test used to quantitatively assess an individual's ability to use visual, proprioceptive, and vestibular cues to maintain postural stability. The objective of this study was to determine the reliability of the SOT to differentiate fallers as compared to non-fallers in individuals with PD. This was a non-randomized single site controlled trial in a clinical setting. 39 subjects with PD (age 70.8 ± 9.9) were identified as fallers or non-fallers based on a history of two or more falls in the past six months. Balance was evaluated using the SOT, Mini-BESTest and MDS-UPDRS-III. Composite scores from the SOT, Mini-BESTest and MDS-UPDRS III were analyzed. There was a statistically significant difference in the mean Mini-BESTest score of 17.8 ± 5.6 for fallers compared to 24.8 ± 2.3 for nonfallers ($p < 0.05$). There was a statistically significant difference in the mean SOT score of 61.8 ± 14.4 compared to 71.8 ± 9.4 for nonfallers ($p < 0.05$). The mean MDS-UPDRS-III score for fallers was 33.6 ± 11.6 and 27.8 ± 9.2 for nonfallers, this was not significant. An ROC curve was constructed to determine the optimal cut-off score for determining a high-risk faller with PD. Our data suggests the SOT is a reliable test to identify PD subjects at risk for falling with a cut-off score of < 67 .

Keywords: SOT, PD, Balance

1. Introduction

Falls are a common symptom of advanced Parkinson's disease (PD) and can cause severe injuries and immobility, and ultimately can limit a person's activities of daily living [1]. Individuals with PD are at an increased risk for falls due to a shuffling gait pattern (small steps and a narrow base of support) and some suffer from episodes of akinesia and freezing of gait, which is characterized by an inability to move the lower extremities. Parkinson's disease affects balance and diminishes the ability to make corrective adjustments in posture to prevent falling [1-3].

There are multiple evaluation tools used to examine balance and stability in people with PD, however few have been shown to be accurate for predicting falls in individuals with PD [2, 4-6]. The Mini-BESTest and the MDS-UPDRS-

III both have demonstrated an ability to predict falls with a cut-off score to differentiate likely fallers from nonfallers.

To date, the Mini-Balance Evaluation Systems Test (Mini-BESTest) has been shown to be the most valid balance test for individuals with PD [5]. It differentiates balance into four underlying systems: sensory organization, anticipatory postural adjustments, postural responses and dynamic balance during gait [5]. It is easy to administer and has excellent reliability and validity. It has been shown to distinguish among different balance abilities in people with PD and predict recurrent fallers with PD [5, 7, 8].

The MDS-UPDRS-III examines motor symptoms with 33 items scored on a scale of 0-4 (4 indicates the highest level of symptom severity). This is a sub-section of the Unified Disease Parkinson's Rating Scale, which is commonly used to quantify symptoms of PD in both clinical practice and

research [9].

Another test that is becoming more commonplace both in the clinic and in experimentation to examine postural stability and balance in individuals with PD is the Sensory Organization Test (SOT). Unlike the Mini-BESTest and the MDS-UPDRS-III, the SOT is an objective measure of postural responses and balance using a platform that measures mechanical displacement under a variety of conditions. The SOT software is sensitive to abnormalities in postural control, somatosensory, visual, and vestibular sensory systems. It offers a composite score that is a percentage based on age-matched controls. It has already been shown that individuals with PD ($n=20$) who were categorized as fallers, scored lower on the SOT than non-fallers with PD.[7]

The instructions for the SOT, similar to the other tests, are standard instructions, which are pre-scripted. The difference between the SOT and the other tests is in how the responses are quantified. Whereas the Mini-BESTest and the MDS-UPDRS are graded by an examiner based on a standard rubric, the SOT grades the responses in an objectively measured fashion and compares the responses to age-matched norms.

Although there has been an increase in use of the SOT in people with PD, to date no cut-off values have been determined to discriminate fallers from non-fallers. The current experiment had two purposes: 1) To compare the SOT, UPDRS III, and Mini-BESTest score in individuals with PD who fall and those who do not fall, and 2) To determine a cut-off SOT score that would differentiate high risk fallers from non-fallers in PD.

2. Methods

2.1. Subjects

The study was organized and conducted at the Adele Smithers Parkinson's Disease Treatment Center of the New York Institute of Technology, College of Osteopathic Medicine (Old Westbury, NY). The study was approved by the IRB, and all participants signed a written informed consent. Volunteers were recruited from the Center as well as from flyers at the offices of local neurologists.

Inclusion criteria: 1) diagnosis of PD by a licensed neurologist; 2) ability to ambulate independently with or without an assistive device; 3) age range between 40 and 80 years. Exclusion criteria: 1) surgical management of PD; 2) currently participating in or receiving balance therapy; 3) any other neurological condition or; 4) diagnosis of a vestibular disorder.

2.2. Table (Subjects)

Thirty-nine subjects (age 70.8 ± 9.9) were placed in a group of fallers or non-fallers. To be placed in the faller group, the subject either had two or more falls within the past six months or a fall resulting in serious injury, or a fall within the past week. Those placed in the non-faller group had no fall

within the past six months.

Table 1. Subject Characteristics.

	Faller Group (n=17)	Non-faller group (n=22)
Male sex, No.	12	17
Age, mean $y \pm SD$	67.8 ± 11.1	72.5 ± 8.5
Years diagnosed mean $y \pm SD$	7.2 ± 5.3	7.4 ± 5.4
UPDRS motor score	33.6 ± 11.6	27.3 ± 9.3
Anti-Parkinsons Medication No. (%)		
Levodopa therapy	17 (100)	22 (100)
Dopamine agonists <i>ropinirole, pramipexole, amantadine</i>	8 (47)	5 (35)
Other anti-parkinsonian agents <i>tolcapone, rasagiline, ensam</i>	13 (74)	18 (82)

2.3. Procedures (Figure 1)

All subjects were subjected to three tests: the MDS-UPDRS-III Motor Scale, the Mini-BESTest and the Sensory Organization Test (SOT). All subjects completed the SOT on the Neurocom® Smart Balance Master (Clackamas, OR.) on the first testing day to provide a familiarization trial to account for any learning effects [7].

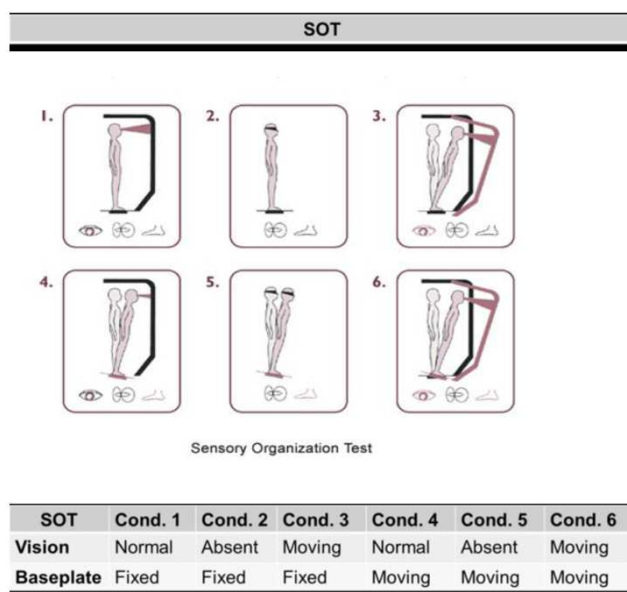


Figure 1. Sensory Organization Test.

The Mini-BESTest, the MDS-UPDRS-III Motor Scale and the SOT were performed on the second visit in a counter-balanced fashion. The score of the SOT administered on the second visit was the score used for analysis. All testing was performed at the same time during the peak 'on' phase of medication and the MDS-UPDRS-III Motor Scale was administered by a certified MDS instructor.

The SOT was performed according to the manufacturer's instructions. The SOT has 6 sensory conditions with three 20-second trials for each condition. Subjects were positioned on the platform by aligning the lateral malleoli with the axis of rotation of the platform. Foot position was marked to allow consistency between trials and sessions. A harness that attaches overhead was fitted to prevent falls without limiting

postural sway. Before each trial, subjects were given the instructions recommended by the manufacturer. A researcher was stationed behind the subject guarding the subject for safety throughout the duration of the test.

3. Results

A total of 39 subjects completed the study and were included in the final analysis. Of these, 19 (48.7%) experienced more than two falls within the past 6-months and were thus classified as fallers.

An independent-samples t-test was conducted to compare Mini-BESTest and SOT scores of fallers and non-fallers. There was a significant difference in the Mini-BESTest scores for fallers ($M=17.7$, $SD=5.6$) and non-fallers ($M=24.8$, $SD=2.4$); $p < 0.001$. There was also a significant difference in the SOT scores for fallers ($M=61.8$, $SD=14.4$) and non-fallers ($M=71.8$, $SD=9.4$) $p = 0.014$. There was no significant difference in the MDS-UPDRS-III scores for fallers ($M=33.6$, $SD=11.6$) and non-fallers ($M=27.8$, $SD=9.3$) conditions; $p = 0.09$.

A Receiver Operating Characteristic (ROC) curve was

constructed and the area under the curve was analyzed to assess the validity of the tests for identifying fallers. The area under the ROC curve was 0.86 (95% CI=(0.73, 0.99), $p < 0.001$) for Mini-BESTest, 0.73 (95% CI=(0.58, 0.89), $p = 0.012$) for the SOT, and 0.66 (95% CI=(0.49, 0.84), $p = 0.08$) for the MDS-UPDRS-III. For the two tests that showed a significant area under the ROC curve, the sensitivity and the specificity at various cut-off scores were further analyzed, and an optimal cut-off score was determined to be the one that maximizes the Youden's index (J) (= sensitivity + specificity -1). The Mini-BESTest < 21 showed sensitivity of 0.63 (95% CI=(0.41, 0.85)) and specificity of 1.00, and SOT < 67 showed sensitivity of 0.63 (95% CI=(0.41, 0.85) and specificity of 0.81 (95% CI=(0.64, 0.98) for identifying fallers. With both tests, sensitivity was not acceptable while specificity was good. When the two tests were combined, however, sensitivity was improved with the specificity remaining at a good level. When the Mini-BESTest < 21 and the SOT < 67 were used in conjunction there was a sensitivity of 0.79 (95% CI=(0.61, 0.97) and specificity of 0.90 (95% CI=(0.78, 1).

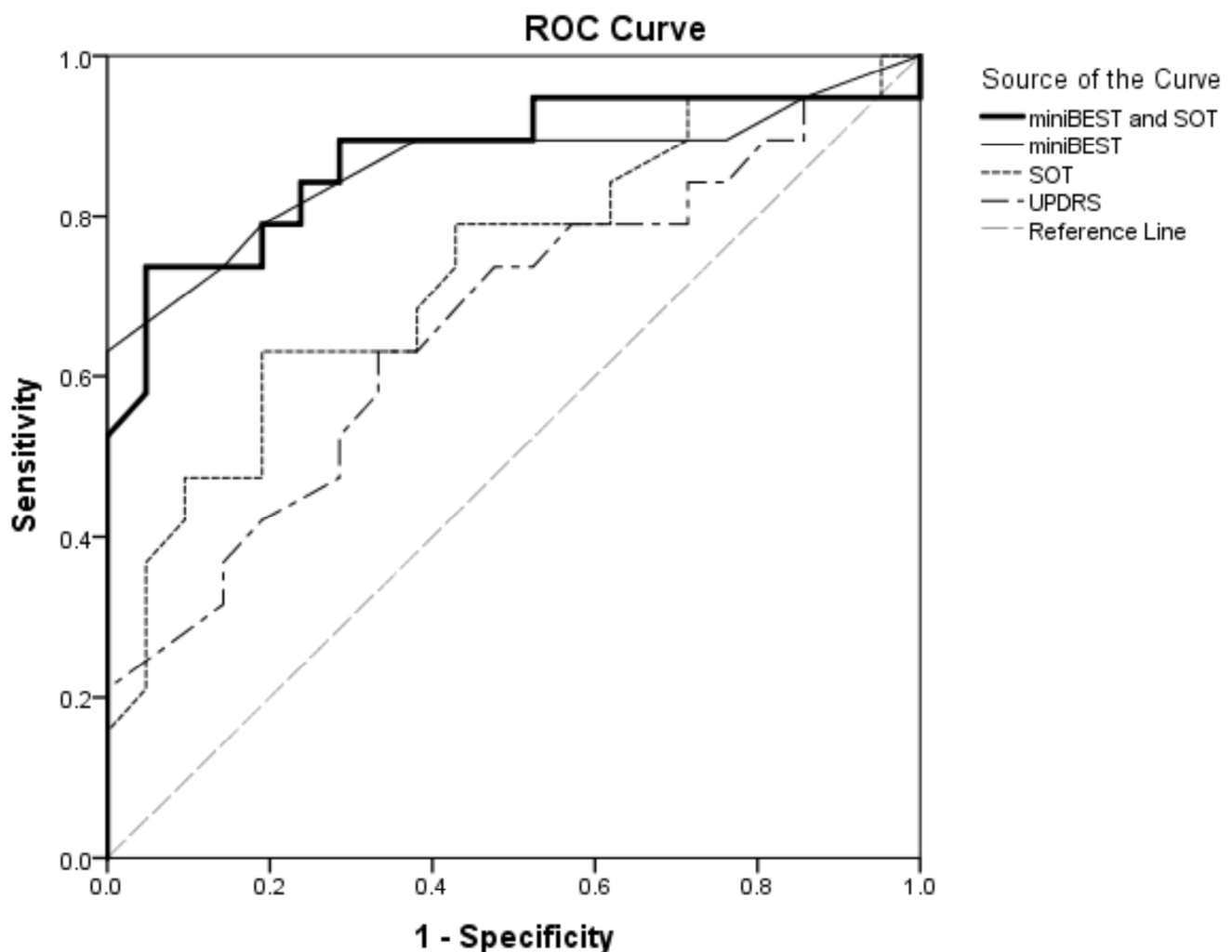


Figure 2. ROC curves for identifying a faller from Min-BESTest, SOT, and UPDRS.

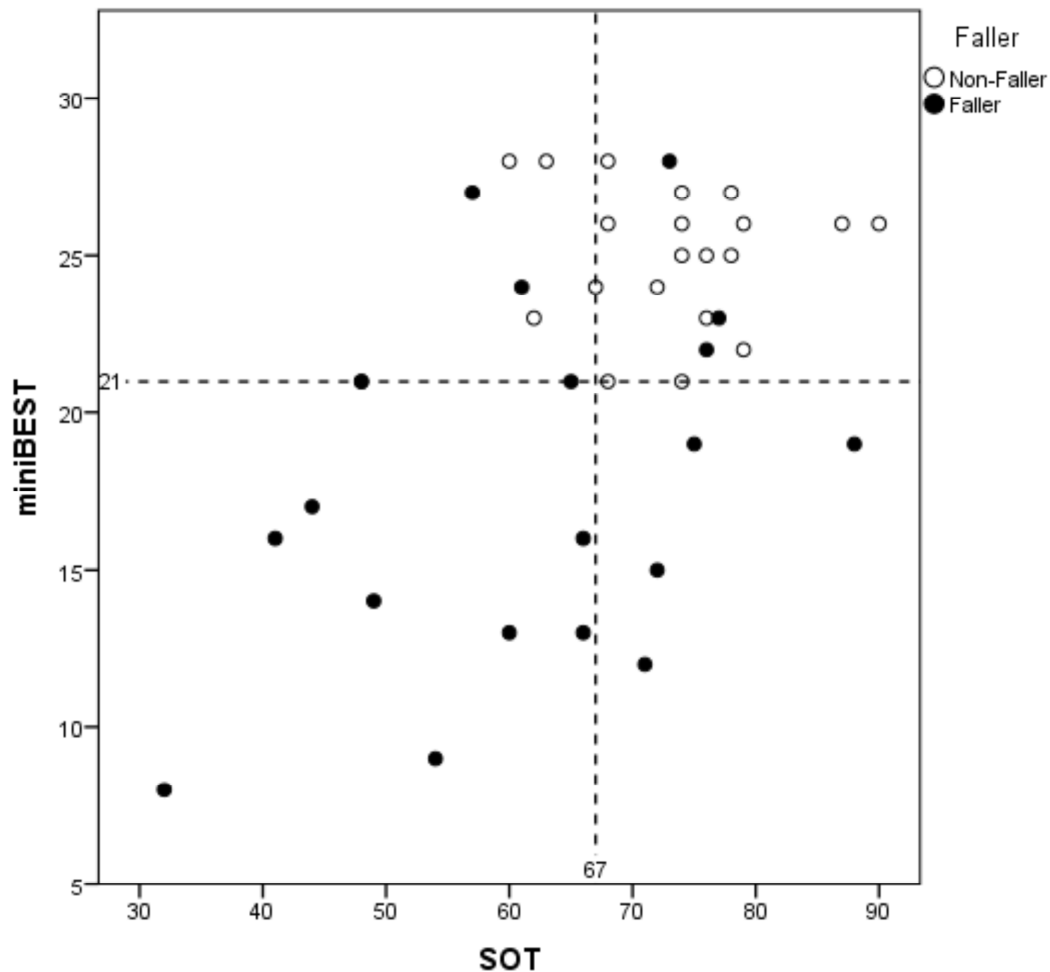


Figure 3. Scatterplot of Mini-BESTest against SOT with optimum cutoffs for identifying a faller.

Reference lines were drawn at Mini-BESTest=21 and SOT=67, and fallers were represented by black dots and non-fallers by white dots. By the criterion for fallers of Mini-BESTest <21 alone, there were 7 false negatives (falsely identified as non-fallers; black dots located at or above the reference line of Mini-BESTest=21) and no false positives (falsely identified as fallers; no white dots located below the line). By the criterion for fallers of either Mini-BESTest<21 or SOT<67, however, there were 3 false negatives (black dots located upper right subdivision by lines) and 3 false positives (white dots located upper left subdivision by lines). The best criterion for identifying fallers was derived when the Mini-BESTest was combined with the SOT (either Mini-BESTest <21 or SOT <67).

4. Discussion

To our knowledge, this is the first experiment to identify a cut-off score to discriminate between fallers and non-fallers in people with PD. The results offer clinicians a valid cut off score sensitive enough to differentiate between individuals with PD who have a history of falls vs. no falls.

Shoneburg and colleagues [10] explained the framework for understanding balance dysfunction in PD. They classified

4 domains that contribute to falls in PD. These were Quiet Stance, which is explained as postural alignment, postural sway, and limits of stability, Reactive Postural Adjustments, which includes adapting posture to a situation and strategizing changes; Anticipatory Postural Adjustments, and Dynamic Postural Control which occurs during different gait speeds and variability [10]. These variables are not the only components of falls in PD. Dual tasking during gait changes focus and increases gait variability (usually slower speed) in PD and contribute to falls. Cognitive function plays a role in balance dysfunction on two levels. A person with PD who is cognitively impaired may make poor or unsafe choices. Additionally, multitasking requires greater focus on postural adjustments and balance and this may play a role in loss of balance during gait and other activities such as turning or when picking up an object. Initiation of movement can also be problematic in PD. Episodes of gait akinesia (freezing of gait) can lead to an increase in festinating steps to try and correct for the lack of postural control that occurs in PD. A festinating gait pattern is characterized by very short, rapid steps which can lead to a fall. The same gait pattern may occur in reverse (retropulsion) which also may lead to a fall.

With all these causes of falls in PD, it is difficult to have one single test that can account for all parameters [10, 11].

There is no consensus on the most appropriate tool for assessing balance in the PD population. Other popular clinical assessments include the Functional Reach Test (FRT), the Timed Up and Go Test (TUG), the Dynamic Gait Index (DGI), the Berg Balance Scale (BBS), the Tinetti Mobility Test (TMT) and the Functional Gait Assessment (FGA). The FRT, TUG, DGI, and BBS all have been shown to be poor predictors of falls in PD [12]. The most common assessment, the BBS, has been noted to have a ceiling effect which is present when the highest score on the scale is unable to discriminate between differences in the upper end of the attribute [8]. Balance assessments that include the TMT, FGA, and Mini-BESTest have all been shown to have validity and reliability for assessing balance in PD with population specific cutoff scores, however, the Mini-BESTest is currently the gold standard [1, 5, 12].

Whereas the SOT had moderate reliability, the Mini-BESTest was a better assessment of distinguishing fallers, and the combination of both the SOT and Mini-BESTest was more reliable to differentiate fallers from non-fallers. It is likely that due to the test itself, the Mini-BESTest measures more areas beyond simple postural stability and reasons for falling are varied, not just postural stability. The SOT had moderate reliability because it only tests for quiet stance, postural control, adaption of postural responses such as a change in surface and vestibular alteration. It does not account for cognitive deficits, multi-tasking, or gait variation. Although we established a clinical cut-off score for a high risk faller in PD using the SOT, it would be clinically negligent to solely base an individual with PD's risk of falling solely on this test.

Study Limitations:

There were some limitations to this study. The reason and type of falls the subjects in the faller group was not recorded. Additionally, we did not observe falls after testing was complete. Future studies should evaluate these cut-off scores on the SOT and utilize fall logs to externally validate the predictive clinical tool of the SOT.

Understanding each test and its role in predicting falls in people with PD can help create more effective treatment plans and establish more accurate assessment tools. While it would be ideal to administer several tests at once, it may be impractical and time-consuming in a clinical setting. Identification of the most objective and accurate tests would be clinically useful.

5. Conclusions

The SOT was a reliable test to differentiate fallers compared with non-fallers in PD with a composite score < 67.

There are no conflicts of interest to disclose for any authors.

1. Research project: A. Conception: DiFrancisco-Donoghue, Werner, Organization: DiFrancisco-Donoghue, Apoznanski, Werner. C. Execution: DiFrancisco-Donoghue,

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2. Statistical Analysis: A. Design: Jung B. Execution: Jung, Apoznanski C. Review and Critique: DiFrancisco-Donoghue, Jung, Werner.

3. Manuscript Preparation: A. Writing of the first draft: DiFrancisco-Donoghue, Apoznanski B. Review and Critique: DiFrancisco-Donoghue, Werner, Yao, Apoznanski

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