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**Original Research**

# A New Balance Assessment Tool for Quantifying Sitting Balance in Individuals with Spinal Cord Injury; Development, Validity and Reliability of the Sitting Star Excursion Balance Test (SSEBT)

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**ABSTRACT**

Sitting balance is essential for functional daily activities with certain significance for patients with spinal cord injuries (SCI). Assessment of sitting balance determines the individual's ability to control posture. Independence in daily activities requires appropriate stability in all movement plates. However, no testing protocol or tools have been developed to quantify sitting balance in all reaching directions. Thus, this study aimed to develop a comprehensive sitting balance test and determine the reliability, and validity of the Sitting Star Excursion Balance Test (SSEBT) for this population. 101 patients with chronic SCI participated voluntarily. To examine the reliability and validity of SSEBT, Pearson's correlation coefficient and the interclass correlation coefficient were used at a significant level of $p < 0.01$. The SSEBT was highly correlated with the Modified Functional Test ($r = 0.84$), indicating the concurrent validity between the two tests. The inter Intra-class Correlation Coefficient was above 0.90, also the Inter-Class Correlation Coefficient for SSEBT was higher than 0.90. The results of this study revealed that SSEBT has good validity and reliability to measure the sitting balance in patients with spinal cord injuries. Therefore, this novel test is recommended for the measurement of sitting balance in this population.

**Keywords:** Sitting Balance, Spinal Cord Injury, Postural Stability, Psychometric

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## INTRODUCTION

Impaired postural control is one of the consequences of spinal cord injuries (SCIs) [1, 2]. Impaired balance is a significant contributing factor to decreased mobility following SCIs [3]. Falls occur frequently in individuals with motor incomplete SCIs [4]. Therefore, balance is an important construct for physical therapists to measure in this population. Few balance tests with sufficient psychometrics are available in the SCI population and are an essential component of daily activities such as eating, dressing, and ambulation. Therefore, in people with SCI, functional activities and independence in daily living activities are deeply affected [5].

In healthy individuals and particularly athletes, the ability to sit unsupported requires the coordinated use of the whole body, the lower extremities, the trunk, upper extremities, and the head, along with inputs from the sensory systems [6, 7, 8, 9]. In people with SCIs, unsupported sitting is impaired due to complete or partial loss of sensory or motor control of the body. The extent of the disorder depends on the level of the injury [10, 11]. People with SCIs are dependent on wheelchairs for movement. These people do daily activities of life in a sitting position, and having a good balance to perform functional activities in different directions safely and particularly is essential [12]. Falls are common among individuals living with spinal cord injuries. A recent review estimated that approximately 69% of non-ambulatory individuals with SCIs experience at least one fall in a period of 6 to 12 months [13]. Injuries [14], hospitalization [15], and the fear of falling reduce physical and social activities [16]. As a result, sitting balance in patients with SCIs is very important and necessary to achieve better performance in functional activities, greater independence, and reduction of complications [17].

Trunk stability is the third most important goal in the rehabilitation of people with SCIs, which can significantly improve the patient's quality of life [18]. Physiotherapy in people with SCIs usually includes physical activity and regular training in functional activities by the principles of re-learning movement in a sitting position [19, 20]. Related tools for assessing trunk control to support strategies implemented to train sitting balance without the support and their effectiveness in people with SCIs is a key issue in rehabilitation and follow-up of people with SCIs [21].

There are two basic ways to evaluate postural stability. The first method is based on lab settings [21]. This method includes tools such as force plates and surface electromyography used to measure changes in the center of pressure, postural oscillation, and muscle activity [22]. These devices provide accurate data without prejudice but are not used widespread for a variety of reasons. The first reason is that they are expensive. The second reason is that these tools need a separate and convenient space to use and install. Third, the operational personnel of these tools must be trained to collect and analyze data. As a result they not available tools in all clinical settings [23]. The second method is based on clinical trials, which is advantageous in that it applies to any type of patient, in addition, it does not require high-level equipment and their results are easy to interpret [2].

In the literature, some measures, instruments, and tools have been used to assess unsupported sitting in SCI in the laboratory, such as force plate transducers,10–12 piezo-resistive pressure systems, and limits of stability, and in clinical settings, such as the Modified Functional Reach Test, Sitting Balance Measure, Modified Motor Assessment Scale, Modified Sitting Balance Score, Hand-Held Dynamometry, Set of Assessment Tools for Measuring Unsupported Sitting, Functional Reach, Reach Area, Bilateral Reach, Modified Functional Reach Test, Trunk Control Test and Modified Version of the Function in Sitting Test [2, 10, 23, 24, 25].

Daily activities and movements are performed in several movement plates, so the assessment of sitting balance control should include all direction movements that are usually required in transitions. There is a need for assessment instruments that are quick and easy to conduct, and suitable for clinical practice. Also, evidence of an intervention's effectiveness depends on, among other things, the use of a common set of valid and reliable instruments that are responsive to change and reflect clinically important outcomes [25, 26]. Therefore, this study aimed to develop and investigate determine the reliability and validity of the Sitting Star Excursion Balance Test (SSEBT) in individuals with SCIs.

## MATERIAL AND METHODS

### Participants

Subjects were purposefully selected among the patients with spinal cord injuries referred to rehabilitation centers in Tehran. 101 Patients with SCI (age M= 41.35 years and SD= 12.28) participated in the study after signing the consent form.

### Inclusion and Exclusion Criteria

The inclusion criteria were: sitting ability without support for at least 10 seconds; individuals over 16 years old; at least one year has passed since the injury and ability to communicate and follow instructions.

Exclusion criteria included: unstable cardiovascular disease; having a history of fainting or dizziness and taking medications that cause dizziness or imbalance; the presence of musculoskeletal deformity in the upper limb; serious complications related to SCI (such as pressure sores, shortness, or significant increase in muscle tone, and impaired blood pressure); and any head injuries and disorders were related to psychiatry. Their average duration of injury was 10.25 years (from 2 years to 40 years) and their injury level was from T11 to S1. One year after injury is classified as chronic because reaching a steady state of neurological recovery is approximately 12 months after injury.

### Sitting Star Excursion Balance Test (SSEBT)

SSEBT was performed on a circular grid 3 meters in diameter with eight calibrated lines in different directions at a 45-degree angle to each other, printed on a banner, and placed on the ground as a poster (Figure 1).

**Figure (1).** Sitting Star Excursion Balance Test(SSEBT)

For performing SSEBT, an unsupported sitting position was defined as sitting on the floor without any provision so that the legs were stretched out about 10 centimeters apart from each other. The reach was started from the front direction. Then the subject did the right hand directions, counterclockwise, and the left hand directions, according to the clockwise direction. During reach, the fixed hand was placed crosswise on the shoulder to neutralize any compensatory stabilization of the upper limb. The distance from the distal contact point of the reaching hand to the center of the star is the distance of access. In case of an imbalance (unable to return to the starting position while performing the reaching, putting body weight on the reaching hand, touching the ground with points other than the fingertips during the reaching, touching more than once with the reaching hand) the reach was repeated. Each subject performed the reach in each direction three times and the average was calculated. Reaching for each direction was clockwise for the left hand and counterclockwise for the right hand. To normalize the measurements, the distance was obtained from the length of the arm and trunk (sitting by flexing the shoulder(glenohumeral joint) 180 degrees with full extension of the elbow, wrist, and fingers pointing to the ceiling. The distance between the ground and the distal end of the third finger was measured divided by the reaching score and multiplied by 100. In this way, the reaching distance is determined as a percentage of the length of the upper extremity and trunk. To control the learning effect of the test, subjects were provided 3 trials for each direction during the warm-up to get familiar with the test.

### The Modified Functional Reach Test (MFRT)

The MFRT has been reported with high test-retest reliability in healthy individuals (ICC=0.94 -0.96), people with stroke (ICC= 0.92- 0.96), and people with SCI (ICC=0.85-0.94). It also has a significant correlation with the Functional Independence Measure (r=0/49, p <0/05) and the ability to distinguish functional differences between different levels of injury (between tetraplegia and paraplegia and high and low levels of paraplegia) in people with SCIs [27]. To take the MFRT, the subject was placed in a sitting position on a chair with an arm facing the wall and a yardstick level with the patient's acromion was installed on the wall. The hip, knee, and ankle were bent at a 90-degree angle of flexion and the sole was flat on the floor. While the subject was sitting on a chair with his or her upper limbs bent to a 90-degree angle of flexion, initial reach was measured from the distal end of the third finger along the meter. The instructions included leaning as far forward as possible without turning or touching the wall. The distance traveled was recorded in centimeters. If the subject was unable to raise the injured arm, the distance traveled by the landmark (patient's acromion) was recorded as the average of reach of three trials performed for statistical analysis.

### Data analysis

Descriptive and inferential statistics were used to analyze the data. Kolmogorov-Smirnov test was used to measure the normality of the data. Logical validity was evaluated using face validity and statistical validity in comparison with the MFRT using Pearson's correlation coefficient. To determine the reliability of the test and retest and the reliability between the two testers, Cronbach's alpha was used to calculate the interclass correlation coefficient (ICC). All analyses were performed at the significant level of p <0.01 using SPSS software (version 22).

## RESULTS

### Validity

The result of logical validity (Face Validity) showed that after considering the instrument by 10 sports medicine experts, they stated that SSEBT can measure sitting balance. The result of statistical validity using Pearson's correlation coefficient indicates acceptable concurrent validity between the total score (average reach in eight directions) as the index of SSEBT with the average of three repeats of the MFRT (Table 1).

Table 1. Criterion Validity (Concurrent Validity) results between the Sitting Star Excursion Balance Test and the Modified Functional Reach Test

| | Sitting Star Excursion Balance Test | Modified Functional Reach Test |
|---|---|---|
| Sitting Star Excursion Balance Test | 1 | |
| Modified Functional Reach Test | 0.844** | **1** |

**Significance at 99% confidence level (p <0.01)
* Significance at 95% confidence level (p <0.05)

## Interrater Reliability

To obtain the degree of Interrater Reliability, the two raters simultaneously recorded the results of the evaluation in each direction independently and separately. The right hand and the left hand showed very high Interrater Reliability (ICC = 0.996). In addition, Interrater reliability in all directions is presented in (Tables 2 and 3).

Table 2: Interrater Reliability (Right Hand Assessment) of Sitting Star Excursion Balance

| Assessment of the right hand counterclockwise | Rater | Average | Standard deviation | *Cronbach's alpha* |
|---|---|---|---|---|
| Interrater Reliability | Rater A | 65.17 | 21.437 | **0.996** |
| | Rater B | 65.11 | 21.565 | |
| Forward | Rater A | 82.36 | 6.574 | **0.965** |
| | Rater B | 82.61 | 6.948 | |
| Forward-Left | Rater A | 73.30 | 7.608 | **0.967** |
| | Rater B | 73.29 | 8.446 | |
| Left | Rater A | 54.39 | 12.481 | **0.992** |
| | Rater B | 54.61 | 12.601 | |
| Backward-Left | Rater A | 22.54 | 9.404 | **0.985** |
| | Rater B | 22.38 | 9.583 | |
| Backward | Rater A | 51.10 | 7.409 | **0.969** |
| | Rater B | 50.71 | 7.914 | |
| Backward- Right | Rater A | 73.13 | 7.782 | **0.970** |
| | Rater B | 73.95 | 7.840 | |
| Right | Rater A | 81.80 | 6.203 | **0.958** |
| | Rater B | 80.66 | 6.567 | |
| Forward-Right | Rater A | 83.49 | 5.714 | **0.953** |
| | Rater B | 82.64 | 6.316 | |

Table 3. Interrater Reliability (Left Hand Assessment) of Sitting Star Excursion Balance Test

| Assessment of the left hand clockwise | Rater | Average | Standard deviation | *Cronbach's alpha* |
|---|---|---|---|---|
| Interrater Reliability | Rater A | 62.75 | 20.129 | **0.996** |
| | Rater B | 62.48 | 20.194 | |
| Forward | Rater A | 82.82 | 6.139 | **0.952** |
| | Rater B | 81.92 | 5.835 | |
| Forward-Right | Rater A | 65.17 | 7.942 | **0.975** |
| | Rater B | 64.64 | 8.159 | |
| Right | Rater A | 53.18 | 8.724 | **0.977** |
| | Rater B | 52.58 | 8.960 | |
| Backward- Right | Rater A | 23.80 | 10.033 | **0.984** |
| | Rater B | 23.71 | 9.862 | |
| Backward | Rater A | 49.24 | 7.302 | **0.971** |
| | Rater B | 49.01 | 7.651 | |
| Backward-Left | Rater A | 70.59 | 7.016 | **0.957** |
| | Rater B | 70.45 | 7.552 | |
| Left | Rater A | 78.99 | 7.229 | **0.967** |
| | Rater B | 78.77 | 7.876 | |
| Forward-Left | Rater A | 78.22 | 6.719 | **0.966** |
| | Rater B | 78.76 | 6.939 | |

## Test-Retest Reliability

To measure test-retest reliability, the results of the evaluation of the first evaluator from a single group of subjects at two different times with an interval of 10 days apart in each direction were recorded separately. The statistical results of the intra-class correlation coefficient show that (SSEBT) has a very high test-retest reliability, both in the evaluation of the right and left hand (ICC = 0.995 and ICC = 0.993). In addition, test-retest reliability in all directions is presented in Tables 4 and 5.

Table 4. Test-Retest Reliability (Right Hand Assessment) of Sitting Star Excursion Balance Test

| Assessment of the right hand counterclockwise | Rater | Average | Standard deviation | *Cronbach's alpha* |
|---|---|---|---|---|
| Test-retest Reliability | Rater A (First Trial) | 65.17 | 21.437 | **0.995** |
| | Rater A(Second Trial) | 64.40 | 21.103 | |
| Forward | Rater A (First Trial) | 82.36 | 6.574 | **0.974** |
| | Rater A(Second Trial) | 80.15 | 6.629 | |
| Forward-Left | Rater A (First Trial) | 73.30 | 7.608 | **0.962** |
| | Rater A(Second Trial) | 72.03 | 7.729 | |
| Left | Rater A (First Trial) | 54.39 | 12.481 | **0.987** |
| | Rater A(Second Trial) | 53.97 | 11.063 | |
| Backward-Left | Rater A (First Trial) | 22.54 | 9.404 | **0.981** |
| | Rater A(Second Trial) | 21.90 | 8.711 | |
| Backward | Rater A (First Trial) | 51.10 | 7.409 | **0.957** |
| | Rater A(Second Trial) | 50.85 | 8.374 | |
| Backward- Right | Rater A (First Trial) | 73.13 | 7.782 | **0.983** |
| | Rater A(Second Trial) | 75.56 | 8.170 | |
| Right | Rater A (First Trial) | 81.08 | 6.203 | **0.975** |
| | Rater A(Second Trial) | 79.20 | 6.461 | |
| Forward-Right | Rater A (First Trial) | 83.49 | 5.714 | **0.957** |
| | Rater A(Second Trial) | 81.56 | 6.280 | |

Table 5. Test-retest Reliability (Left Hand Assessment) of Sitting Star Excursion Balance

| Assessment of the left hand clockwise | Rater | Average | Standard deviation | *Cronbach's alpha* |
|---|---|---|---|---|
| Test-Retest Reliability | Rater A (First Trial) | 62.75 | 20.129 | **0.993** |
| | Rater A(Second Trial) | 61.73 | 20.168 | |
| Forward | Rater A (First Trial) | 82.82 | 6.139 | **0.978** |
| | Rater A(Second Trial) | 80.45 | 6.207 | |
| Forward-Right | Rater A (First Trial) | 65.17 | 7.942 | **0.985** |
| | Rater A(Second Trial) | 62.41 | 8.166 | |
| Right | Rater A (First Trial) | 53.18 | 8.724 | **0.981** |
| | Rater A(Second Trial) | 51.57 | 8.098 | |
| Backward- Right | Rater A (First Trial) | 23.80 | 10.033 | **0.984** |
| | Rater A(Second Trial) | 22.29 | 9.636 | |
| Backward | Rater A (First Trial) | 49.24 | 7.302 | **0.971** |
| | Rater A(Second Trial) | 50.15 | 6.655 | |
| Backward-Left | Rater A (First Trial) | 70.59 | 7.016 | **0.956** |
| | Rater A(Second Trial) | 71.07 | 7.178 | |
| Left | Rater A (First Trial) | 78.99 | 7.229 | **0.962** |
| | Rater A(Second Trial) | 78.83 | 7.419 | |
| Forward-Left | Rater A (First Trial) | 78.22 | 6.719 | **0.979** |
| | Rater A(Second Trial) | 77.05 | 9.023 | |

## DISCUSSION

The SSEBT was highly correlated with the MFRT (r = 0.84), indicating the concurrent validity between the two tests. The inter Intra-class Correlation Coefficient was above 0.90, also the Inter-class correlation coefficient for SSEBT was higher than 0.90. The results of this study revealed that SSEBT has good validity and reliability to measure the sitting balance in patients with spinal cord injuries.

### Validity

Validity is the degree to which a tool measures the construct(s) it purports to measure [28]. In this study, to determine the face validity of SSEBT, 10 sports medicine experts confirmed that SSEBT can measure the sitting balance. The results of statistical analysis showed that SSEBT had acceptable criterion validity (Concurrent Validity). The validity of the test was evaluated using Pearson's correlation coefficient showed a high validity (r= 0.844). According to Safrit and Wood classifications, the values obtained from validity coefficients equal to or higher than 0.90 are desirable, and Values above 0.80 are acceptable [29]. According to the various cases that have been done in the field of instrument validity in this research; validity evaluation by the judgment of relevant experts as well as the use of validated tests and statistical validity methods can be considered important features in determining the validity of SSEBT.

### Reliability

Reliability is the grade to which the measurement is free from measurement error [28]. High repeatability is important and necessary for a device. In this study, the reliability was investigated using the Interclass Correlation Coefficient (ICC) [29]. The Reliability Coefficient Test Values are considered excellent if above 0.9, good if 0.8-0.9, acceptable if 0.7-0.8, debatable if 0.6-0.7, Weak if 0.5-0.6 and unacceptable if less than 0.5 [41]. The Interrater Reliability results were obtained both in the right and left hand assessments (ICC = 0.99), as well as the test-retest reliability results in both the right and left hand assessments (ICC = 0.995 and ICC = 0.993). The reliability of the SSEBT can be respected backed by the various cases in the field of reliability measurement in this study; The appropriate time interval between test-retest reliability can be selected (one to two weeks is considered appropriate) [29], The use of appropriate statistics to measure reliability (Intra-Class Correlation Coefficient) and the values obtained from reliability coefficients higher than 0.9 in all directions of the test.

### Limitations of the Study

One of the limitations of the present study was conducted during the pandemic, which made it difficult for subjects to access a wide range of the SCI population. It is possible that testing on a larger number of subjects and classifying subjects with different demographics and clinical conditions could contribute to better results. Another limitation is regarding the SSEBT on the ground, as most people with spinal cord injuries use a wheelchair for ambulation, the SSEBT was performed on the ground, given that the placement on the wheelchair and the corresponding height can affect postural stability. Generalization of SSEBT results to sitting balance on a wheelchair should be done with caution.

### Conclusion

Overall, the study results showed that SSEBT is a valid and reliable tool for measuring the sitting balance in people with SCI. Performing a balance test while sitting on the ground by eliminating height and fear of falling from a wheelchair provides a condition that a person with SCI can challenge her stability and range of motion in all movement directions with confidence and without fear of falling. This can help to find out about wider limits of stability Therefore, it can be recommended to assess balance as one of the components of physical fitness related to movement in sports for the disabled, as well as rehabilitation centers and physiotherapy clinics.

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**Informed Consent Statement:** Informed consent was obtained from all subjects involved in the study.

**Data Availability Statement:** Data will be available at request.

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## ابزار نوین ارزیابی تعادل برای سنجش تعادل نشسته در افراد مبتلا به ضایعه نخاعی: توسعه، روایی و پایایی آزمون تعادل ستاره نشسته

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چکیده

تعادل نشسته در بیماران مبتلا به ضایعه نخاعی برای دستیابی بهتر به اجرای فعالیت‌های عملکرد روزانه بسیار مهم و ضروری است. ارزیابی تعادل نشسته توانایی فرد را برای کنترل پاسچر مورد بررسی قرار می‌دهد. استقلال در فعالیت‌های روزانه نیازمند ثبات مناسب در تمامی صفحات حرکتی است. با این حال، هیچ پروتکل یا ابزاری برای کمی سازی تعادل نشسته در تمامی جهات رسش ایجاد نشده است. بنابراین، این مطالعه با هدف ایجاد یک آزمون تعادل نشسته جامع به همراه تعیین روایی و پایایی آزمون تعادل نشسته ستاره برای این جمعیت انجام شد.۱۰۱ بیمار دارای آسیب طناب نخاعی مزمن به‌صورت داوطلبانه در پژوهش شرکت کردند. برای بررسی روایی و پایایی آزمون تعادل ستاره نشسته از ضریب همبستگی پیرسون و ضریب هم بستگی درون رده ای در سطح معناداری $p < ۰/۰۱$ استفاده شد. بین آزمون تعادل ستاره نشسته با آزمون رسش عملکرد تعدیل شده هم بالایی بود ($r = ۰/۸۴$) که نشان‌دهنده روایی همزمان بین دو آزمون می‌باشد. ضریب هم بستگی درون رده ای بین دو آزمونگر بالای ۰/۹۰ همچنین ضریب هم بستگی درون رده ای برای دو تکرار آزمون نیز بالای ۰/۹۰ بود. نتایج این مطالعه نشان داد که آزمون تعادل ستاره نشسته از روایی و پایایی خوبی برای اندازه‌گیری تعادل نشسته در بیماران مبتلا به ضایعه نخاعی برخوردار است. بنابراین این آزمون جدید برای اندازه‌گیری تعادل نشسته در این جامعه توصیه می‌شود.

**واژ های کلیدی:** تعادل نشسته، آسیب طناب نخاعی، ثبات پاسچر، روان سنجی