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# Reliability of measurements obtained with a modified functional reach test as a balance assessment tool in subjects with spinal cord injury

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**Abstract**
**Background:** Most studies of balance have been performed with subjects in the standing position. Measures that can be used to predict outcomes regarding the balance of no standing patients with Spinal Cord Injuries (SCI) are not available. Most studies of sitting balance have used instrumentation similar to that used for studies of standing balance. The Functional Reach Test (FRT) is highly reliable, fast and easy to use test to measure standing balance. Thus primary objective of study was to determine whether FRT could be modified for group of individuals with SCI to provide reliable measurements of sitting balance. A secondary objective was to determine whether modified FRT could measure differences in functional reach among different levels of SCI.
**Methods:** Thirty male subjects with SCI were divided into three groups based on injury type. Group 1, 2 and 3 consisted of subjects with C5-6 tetraplegia, T1-4 paraplegia, and T10-12 paraplegia respectively. Subjects sat on similar mat tables against the same backboard, set at 80 degrees. During two sessions, forward reach was measured with a yardstick.
**Results:** Intraclass correlation coefficients were high and varied from 0.90 to 0.97. Post hoc testing revealed that differences occurred between groups 1 and 3 and groups 2 and 3, but not between groups 1 and 2.
**Conclusion:** Test-retest reliability was high with modification of the FRT with a single rater. The measurements reflected differences among levels of lesion. The modified FRT appears to provide reliable measurements of sitting balance in no standing persons with spinal cord injuries.

**Keywords:** Modified functional reach test, sitting balance, spinal cord injuries

## Introduction

Spinal cord injury (SCI) is an insult to the spinal cord resulting in a change, either temporary or permanent, in its normal motor, sensory, or autonomic function [1].

In the United States, the incidence of spinal cord injury has been estimated to be about 40 cases (per 1 million people) per year or 12,000 cases per year [2]. In the Unites states there are around 250,000 individuals living with spinal cord injuries. More than 50% of all cases of spinal cord injury occur in persons aged 16 to 30 years, with a mean age at the time of injury of 33.3 years.

SCI may result in incomplete or complete paralysis of the lower limbs making walking difficult or impossible [3]. Duker T. *et al.* have suggested that patients with complete SCI one week after onset have up to 90% chance of remaining without any sensory motor function and only about 5% of those who do improve will regain functional strength in their legs to allow walking [4]. In patients with an initial motor incomplete SCI, more than 75% regain some form of ambulatory function [5]. Epidemiological studies have shown that there's an increase in the number of individuals with SCI that result in incomplete lesions who have the potential to ambulate [6, 7].

Balance is define as "The ability to maintain the body's center of mass over base of support with minimal posture sway" [8]. The normal control of balance is known to emerge as a result of integration of input from the vestibular, visual & somato-sensory systems. The ability to maintain & control balance is a complex task & as such virtually all neuromusculoskeletal disorder result in some degeneration of this ability [9]. Most studies have measure balance impairments (such as postural sway, weight distribution, or related parameters) rather than balance disability. (The type of balance task that a subject can perform while maintaining an upright position, such as static or dynamic sitting balance) [10]. Sitting involves not only the ability to maintain sitting posture, but also the ability to reach for a variety of objects located both within and beyond arm's length [18]. Sitting disability is a common problem after spinal cord injury [11, 12, 13, 14]. Recovery of sitting after spinal cord injury is important for individuals because sitting is a skill that is critical to independent living [15, 16, 17]. Furthermore, sitting ability has been shown to be use full prognosis indicator for outcome for this population [18, 19, 20}. The disability in reaching tasks arises not only from the impairment, but also from the tendency to adapt behavior to avoid the threat to balance [21]. Restoration of sitting balance is one of the goal of rehabilitation; however, the effect of sitting Balance training with spinal cord injury patient has not been specifically investigated [22, 23, 24].

Performance of seated reaching tasks required the coordination motions of trunk and upper limbs [25, 26, 27] Healthy subjects are able to reach significantly further when feet are in contact with the ground compared with when they are not [28]. However, the role of lower limb is not only to provide larger base of support; according to the recent studies, the lower limb also play an active role in balance [25, 29, 30, 31, 32]. Several factor have been identified that influence the contribution of lower limb to balance in sitting. Distance and direction of reach, seat height and extend of thigh support on the seat have all been shown to affect the magnitude of the load born through the feet and in some cases also the activity in leg muscle [25, 29, 30, 31, 32, 33].

Several studies have found that change in balance ability correlated significantly with change in function [19, 34, 35, 36, 37]. The relation between balance impairment (such as weight distribution or posture sway) and function, whether assessed by balance disability, mobility, or ADL is clear. There are consistent findings suggestive of positive relationship between balance disability and other aspect of function, such as mobility, ADL, and fall [38, 39, 40, 41].

Most studies of balance have been performed with subjects in the standing position, but studies of sitting balance have also been reported [42-45]. Most studies of sitting balance have used instrumentation similar to that used for studies of standing balance [42, 43]. Some balance tests that are less dependent on instrumentation have been introduced, but these measures are designed for persons who can ambulate [46, 47]. Only a few tests exist for clinical balance assessment of non-standing individuals. One such test is the Seated Posture Control Measure [44, 45]. Which is designed to document a child's posture in his or her seating system and to assess his or her ability to function. Unfortunately, the test is quite long (36 items) and may not be generalizable to persons with a variety of impairments, including persons with spinal cord injury (SCI) [44, 45].

The Functional Reach Test (FRT) [48] can be used to measure standing balance. In our view, the FRT is fast and easy to use. A study using the FRT with 217 elderly male veterans (aged 70-104 years) demonstrated that the test provides highly reliable measurements of balance and can be used to predict the risk of falling [49]. The FRT also can be used to estimate physical frailty [50] and to demonstrate change in response to treatment [51]. In the study by Weiner *et al.*, [51] 28 inpatient male veterans were tested every 4 weeks during a regular physical therapy program, and increases in functional reach and other mobility measures were documented. No control was placed on the therapy received. Studies of FRT have also demonstrated strong reliability and validity [48-51]. The FRT, therefore, possesses attributes that can make it a meaningful and accessible test.

For the purposes of study, sitting balance is defined as the ability of a person to maintain control over upright posture during forward reach without stabilization [52]. Any reaching task will be a challenge to upright control for persons with partial or complete paralysis of the trunk and arms.

Hence, the primary purpose of our study was to determine whether the FRT could be modified for a group of individuals with SCI to provide reliable measurements of sitting balance. A secondary purpose was to determine whether the modified FRT could measure differences in functional reach among different levels of SCI.

## Material and methods

An observational study was conducted at Government Physiotherapy College, Ahmedabad. The study was performed only in a single session. 30 (Thirty) male subjects who were diagnosed with spinal cord injury with complete lesion according to ASIA impairment scale (either ASIA A or ASIA B) [53] and who had completed at least 1 month of their initial phase of rehabilitation were taken as study participants. The subjects were between 18 and 45 years of age (X=30.97, SD=8.32.To be included in the study, patients must able to sit independently of a seating system with only a backboard for support, having no deformities in upper extremities and able to assume and maintain 90 degrees of shoulder flexion.

All subjects had complete lesions according to the American Spinal Injury Association's (ASIA) Impairment Scale [53]. The lesions, therefore, were classified as either ASIA A or ASIA B, because both classifications are for complete motor injuries. The difference between the categories is in sensation. There is no sensation below the level of the lesion in ASIA A lesions, but sensation can be partially spared in ASIA B lesions. We chose these type categories of lesions to ensure that there would be no lower-extremity motor function to allow the subject to weight bear on the feet when reaching forward in sitting.

Subjects were assigned in three groups based solely on level of injury: Group 1 (n=10) consisted of subjects with C5-6 tetraplegia, Group 2 (n=10) consisted of subjects with T1-4 paraplegia and Group 3 (n=10) consisted of subjects with T10-12 paraplegia.

## Instrumentation

A yardstick was attached horizontally to a wall by Velcro or tape. The method of attachment varied, depending on the site of data collection. According to Duncan *et al.*, [54] the method used to attach the yardstick is not crucial. All subjects sat on a narrow mat table or a padded weight bench, which were of similar width (about 61 cm [24 in]). The same backboard was used and kept at the same angle of 80 degrees for all subjects. This angle allowed all subjects to sit back and relax between trials. The backboard used in this study is also typically used for supporting sitting activities during rehabilitation of patients with SCI.

**Fig 1:** The backboard supporting sitting with SCI

### Procedure

Subjects were screened to be eligible for the study according to inclusion and exclusion criteria. A complete assessment of each patient was done. Muscle force (manual muscle testing), range of motion, and the presence of musculoskeletal deformities in the upper extremity used in reaching were examined at the time of the testing. The presence of inadequate muscle force to maintain shoulder flexion during reaching (as measured by a break test of the shoulder flexors), inadequate range of motion, or musculoskeletal deformity meant elimination from the study. Spasticity, a common sequela in persons with SCI, was not part of the inclusion or exclusion criteria. Spasticity was not measured in any subjects.

Subjects who were found eligible for the participation in the study were requested to sign informed consent forms.

The procedure for the collection of data closely followed the procedure described by Duncan *et al.* [54] Once each subject was positioned on the mat table, the yardstick was placed along the subject's shoulder at the level of the acromion. Subjects sat in the same position for each trial. Their hips, knees, and ankles were positioned with 90 degrees of flexion, and there was 5.08 cm (2 in) of clearance between the popliteal fossa and the mat table. Foot support was provided, if necessary, with a rubber floor mat to ensure proper sitting position. The backboard was placed behind each subject for support.

**Fig 2:** Initial reach

**Fig 3:** Maximal forward reach

Initial reach was measured with each subject resting against the backboard with an upper-extremity flexed to 90 degrees. The anatomical landmark used to measure reach was the ulnar styloid process. Because the subjects with tetraplegia in our study could not make a fist, this landmark was used instead of the third metacarpal, which was used in the original studies of FRT [48-51]. The ulnar styloid process is a prominent landmark and was proximal enough to allow accurate measurements to be taken for all subjects. Subjects used the nonreaching upper extremity for counterbalance only (e.g., no weight bearing or holding on was allowed). The subjects were guarded for safety, and the trial was repeated if the subject required assistance to recover to the backboard.

Two sites were used for data collection. Limitations of the physical facilities at one of the data collection locations necessitated that all 8 subjects who were tested there use their left upper extremity. The remaining 22 subjects who were tested at the other facility used their right upper extremity. All methods were otherwise the same between the sites.

Each subject had two practice trials of maximal forward reach, followed by three trials during which data were collected. The mean of these three trials was recorded. Following the initial three trials, each subject left the testing area for 10 minutes and then returned to undergo repeated testing using the same procedure. A single rater (SML) collected all data for this study.

### Statistical methods

Test-retest reliability was studied using the intraclass correlation coefficient (ICC) because there was a single rater [55]. Because a secondary purpose of our study was to determine whether the modified FRT could measure differences among levels of lesion, a one-way analysis of variance (Anova) was used to test for differences among the means for reach in the three groups. A Newman-Keuls test was used to discern differences among group means and to ensure that Type I error was minimized [55].

Data analysis and calculations were performed manually as well as by using SPSS software.

Table 1 displays the group statistics of Age Distribution among the 30 subjects.

**Table 1:** Age distribution of the subjects

| Age | Group 1 | Group 2 | Group 3 |
|---|---|---|---|
| Mean (yrs.) | 30.9 | 29.2 | 32.8 |
| SD | 8.837 | 8.741 | 7.829 |

Table 2 displays the group statistics according to ASIA impairment level among the three groups.

**Table 2:** ASIA impairment level among the three groups

| Group | Group 1 | Group 2 | Group 3 |
|---|---|---|---|
| ASIA level A | 5 | 6 | 4 |
| ASIA level B | 5 | 4 | 6 |

**Data analysis of test-retest reliability of measurements**

By analyzing the Intra-class correlation coefficient (ICC) for test-retest reliability of measurements of average reach length obtained with modified FRT for all the three groups, following results were obtained.

Since the data were not normally distributed Spearman's Rank Correlation test was applied for ICC test-retest reliability of average reach length. The p values are significant, which suggests that there is statistically significant strong reliability of measurements obtained with the modified FRT.

**Table 3:** ICC for test-retest reliability of measurements of average reach length

| Group | Spearman's r value | p value |
|---|---|---|
| Group 1 | 0.96 | <0.0001 |
| Group 2 | 0.90 | 0.0008 |
| Group 3 | 0.97 | <0.0001 |

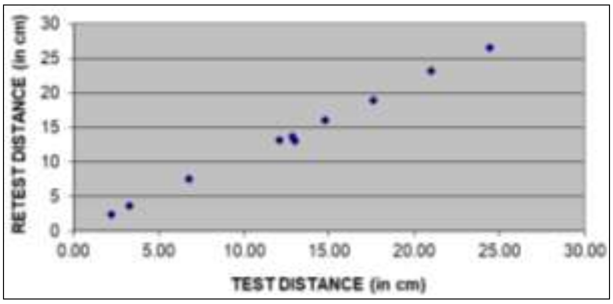


**Fig 4:** Distribution of measurements of average reach length in group 1.

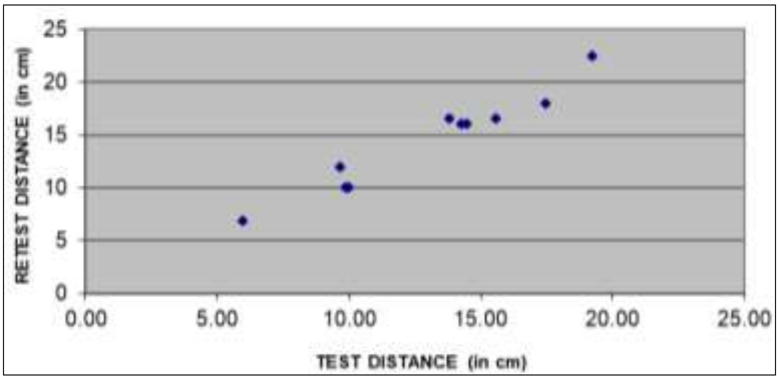


**Fig 5:** Distribution of measurements of average reach length in group 2.

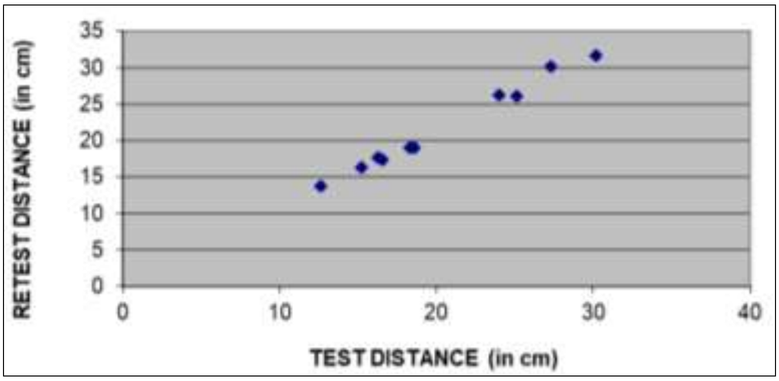


**Fig 6:** Distribution of measurements of average reach length in group 3.

**Data analysis to measure differences among levels of lesion**

The modified FRT was also tested for its ability to distinguish level of lesion. By analyzing the measurements of average maximal reach, following results were obtained.

A one-way analysis of variance (ANOVA) was used to test for differences among the means for reach in the three groups. A Newman-Keuls test was used to discern differences among group means and to ensure that Type I error was minirnized.[55]

The Neuman-Keuls test demonstrated that reach differed only between groups 1 and 3 and groups 2 and 3. There was no difference in reach between groups 1 and 2.

**Table 4:** Mean maximal reach, SD and Range among groups

| Group | Mean maximal reach (cm) | SD (cm) | Range (cm) |
|---|---|---|---|
| Group 1 | 13.78 | 7.861 | 2.40 – 26.53 |
| Group 2 | 14.42 | 4.618 | 6.90 – 22.40 |
| Group 3 | 21.70 | 6.259 | 13.73 – 31.67 |

**Table 5:** Comparison of mean differences between groups

| Comparison | Mean Difference | q value | p value | Significance |
|---|---|---|---|---|
| Group 1 vs 3 | -7.917 | 3.921 | < 0.05 | significant |
| Group 1 vs 2 | -0.6390 | 0.3165 | > 0.05 | Not significant |
| Group 2 vs 3 | -7.278 | 3.605 | < 0.05 | significant |

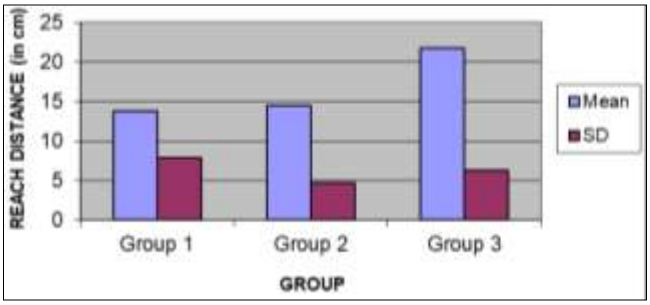


**Fig 7:** Comparison of mean reach and SD between groups

**Discussion**

The results of present study showed that the functional reach test could be modified for a group of individuals with spinal cord injury to provide reliable measurements of sitting balance.

The results indicated high Intraclass correlation coefficients for test-retest reliability with modified functional test with a single rater and varied from 0.90 to 0.97.

Forward reach in a sitting position can be measured reliably via a ruler attached to a wall alongside a patient with SCI. The modified FRT achieved ICCs for test-retest reliability similar to those documented in the original FRT studies [48-51]. Generalizability of test-retest reliability is weak because only one rater was available for data collection. Further study using an interrater design may allow inferences to be generalized to a greater number of situations.

The modified FRT appears to be useful for determining differences in reach among different levels of lesion in persons with SCI. The modified FRT measured differences in reach between groups 1 and 3 ($p < 0.05$) and groups 2 and 3 ($p < 0.05$). There was no difference in the ability to reach between groups 1 and 2 ($p > 0.05$), but mean reach was greater in group 3 compared with groups 1 and 2. This finding appears to be reasonable because people with lower levels of paraplegia tend to have greater functional capabilities than people with higher levels of lesion do. The subjects in group 3 had abdominal and back extensor muscles that were unaffected by their SCI, which apparently gave them a greater advantage in movement control.

The modified FRT did not appear to detect differences between the subjects with tetraplegia (group 1) and the subjects with higher levels of paraplegia (group 2).Although the subjects with higher levels of paraplegia had more unaffected muscles than the subjects with tetraplegia did, reach outcomes were similar. Further study is needed.

Although our study indicates that reliability exists for measurements obtained with the modified FRT, more research is needed to establish validity. Face validity is the assessment of how well a test appears to measure something specific. In our study, subjects with varying amounts of paralysis were asked to reach forward and move without any assistance from their base of support. We believed that each subject had to move to the limits of his stability without loss of balance. We contend that it is important for a test to measure what clinicians and patients believe can affect the patients' functional performance.

According to Campbell [56] in her discussion of face validity, better performances may occur when patients are challenged appropriately by a test, and poorer performances occur when patients believe that the test has no meaning for their problem. Face validity appears to be present in the modified FRT because subjects felt the challenge to their stability and had to make great effort not to fail or a fall would occur.

Future research is needed to obtain evidence that the modified FRT can be used to predict future outcomes (predictive validity) or current balance status. We believe that the modified FRT should be compared with measures of established criterion-related validity. Strengthening validity may demonstrate that the modified FRT is a proper method to answer clinical or research questions.

Studies using the modified FRT would improve its usefulness. Because patients with SCI sit on different support surfaces (cushions and wheelchairs), comparisons could be made only among different products. Measurement of functional reach may cause clinicians to prescribe equipment based on its effects on sitting balance.

Lynch SM [52 studied the reliability of measurements obtained with modified Functional Reach Test in subjects with spinal cord injury. The author reported test-retest reliability was high with modification of the FRT with a single rater. The measurements reflected differences among levels of lesion. The modified FRT appears to provide reliable measurements of sitting balance in non-standing persons with spinal cord injuries. The findings were consistent with the findings of the experimental study.

Test-retest reliability was high with modification of the FRT with a single rater. The measurements reflected differences among levels of lesion. Further study is needed to determine normal values for all levels of lesion, relationships to functional outcomes, and effects of equipment on sitting balance. The modified FRT appears to provide reliable measurements of sitting balance in non-standing persons with spinal cord injuries.

**Conclusion**

Test-retest reliability was high with modification of the FRT with a single rater. The measurements reflected differences among levels of lesion. The modified FRT appears to provide reliable measurements of sitting balance in non-standing persons with spinal cord injuries.

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