Research Report

Reliability of Measurements Obtained With a Modified Functional Reach Test in Subjects With Spinal Cord Injury

Background and Purpose. The primary purpose of this study was to determine whether the Functional Reach Test (FRT) could be modified to provide reliable measurements of sitting balance. A secondary purpose was to determine whether the test could be used to measure differences among levels of spinal cord injury. Subjects. Thirty male subjects with spinal cord injuries were divided into three groups based on injury type. Group 1 consisted of subjects with C5-6 tetraplegia, group 2 consisted of subjects with T1-4 paraplegia, and group 3 consisted of subjects with T10-12 paraplegia. Methods. Subjects sat on similar mat tables (tables varied based on what was available at a given clinic) against the same backboard, set at 80 degrees. During two sessions, forward reach was measured with a yardstick, with a 10-minute break between sessions. Results. Intraclass correlation coefficients (3,2) were high and varied from .85 to .94. *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 and Discussion. 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 nonstanding persons with spinal cord injuries. [Lynch SM, Leahy P, Barker SP. Reliability of measurements obtained with a modified Functional Reach Test in subjects with spinal cord injury. *Phys Ther.* 1998;78:128–133.]

Key Words: *Measurement, Reliability, Sitting balance, Spinal cord injury.*

Suzanne M Lynch

Patricia Leahy[†]

Susan P Barker

[†] Ms Leahy died October 9, 1995.

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Balance has been studied in various ways: by recording biomechanical descriptions of balance reactions,[1–4] by examining physiological components of balance,[5–9] and by investigating changes in the ability of a person to balance across the life span.[8,10–13] These studies provide a basis for understanding human performance. Often, the measurements obtained in research settings are not practical for routine clinical application.

Most studies of balance have been performed with subjects in the standing position, but studies of sitting balance have also been reported.[14–17] Most studies of sitting balance have used instrumentation similar to that used for studies of standing balance.[14,15] Some balance tests that are less dependent on instrumentation have been introduced, but these measures are designed for persons who can ambulate.[18,19] Only a few tests exist for clinical balance assessment of nonstanding individuals. One such test is the Seated Posture Control Measure,[16,17] 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).[16,17]

The Functional Reach Test (FRT)[20] 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.[21] The FRT also can be used to estimate physical frailty[22] and to demonstrate change in response to treatment.[23] In the study by Weiner et al,[23] 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.[20–23] The FRT, therefore, possesses attributes that can make it a meaningful and accessible test.

Measures that can be used to predict outcomes regarding the balance of patients with SCI are not available. Therapists cannot be certain that prescribed wheelchairs or cushions provide patients with the most stable posi-

SM Lynch, PT, NCS, is Staff Physical Therapist, Brain Injury Rehabilitation Unit, St Mary's Hospital, Rochester, NY. She was Clinical Specialist, Spinal Cord Injury, Magee Rehabilitation Hospital, Philadelphia, Pa, at the time of this study. This study was completed in partial fulfillment of Ms Lynch's Master of Science degree in neurologic physical therapy at Philadelphia College of Pharmacy and Science, Philadelphia, Pa. Address all correspondence to Ms Lynch at 39 Havenshire Rd, Rochester, NY 14625 (USA) (slynch@usa.net).

P Lealy, PT, NCS, was Assistant Professor, Philadelphia College of Pharmacy and Science, at the time of this study.

SP Barker, PT, NCS, is Associate Professor, Philadelphia College of Pharmacy and Science.

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tions from which they can function (ie, the best balance). Defining positions that are stable and the effects of equipment on stability would be helpful because persons with paralysis are challenged to maintain their balance during a variety of functional activities.

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

Method

Subjects

Thirty male subjects participated in this study. The subjects were between 18 and 45 years of age ($\bar{X}$=30.8, SD=7.2). Subjects were placed in groups based solely on level of injury. All subjects had complete lesions according to the American Spinal Injury Association's (ASIA) Impairment Scale.[24] 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. All subjects were recruited from the following sources: scheduled medical appointments for Magee Rehabilitation Hospital's (Philadelphia, Pa) SCI follow-up system, teams that participated in wheelchair sports tournaments, and persons readmitted to Magee Rehabilitation Hospital for intensive rehabilitation. All subjects were seen at least 1 month after completion of their initial phase of rehabilitation. Subjects were selected based on their SCI diagnosis and assigned to one of three groups: 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.

To be included in our study, subjects had to be able to sit independently of a seating system with only a backboard for support. The subjects' upper extremities had to be without deformities, and each subject had to be able to assume and maintain 90 degrees of shoulder flexion. 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.

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,[20] 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 (Figure).

Procedure

Informed consent was obtained once subjects were determined to be eligible for the study. The procedure for the collection of data closely followed the procedure described by Duncan et al.[20] 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 (Figure).

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.[20–23] 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 (eg, 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.

* Velcro USA Inc, 406 Brown Ave, Manchester, NH 03108.

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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.

Data Analysis

Test-retest reliability was studied using the intraclass correlation coefficient (ICC[3,2]) because there was a single rater.[25] Calculations were performed using a spreadsheet software package.[†] 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.[25]

Results

Mean reach data for the subjects are presented in the Table. The results indicated that the reliability of measurements obtained with the modified FRT was very strong. The ICCs for test-retest reliability of measurements of average reach length were .94 for group 1, .85 for group 2, and .93 for group 3. There were no differences between the subjects who used their right upper extremity and the subjects who used their left upper extremity to perform the reaches.

The modified FRT was also tested for its ability to distinguish level of lesion. Mean maximal reach was 14.7 cm (SD=7.6, range=3.3–27.4) for group 1, 15.5 cm (SD=4.3, range=7.6–21.3) for group 2, and 22.9 cm (SD=5.6, range=14.7–29.2) for group 3. A one-way ANOVA was used to determine that subjects with lower levels of lesion had a longer reach compared with subjects with higher levels of lesion. 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.

[†] Microsoft Excel 5.0, Microsoft Corp, One Microsoft Way, Redmond, WA 98052.

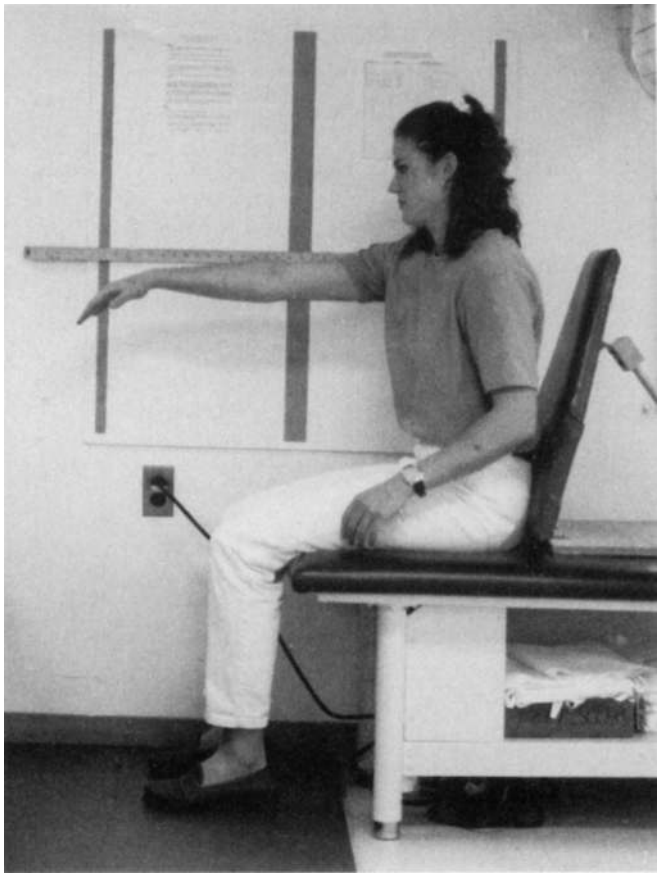

Figure.
Subject demonstrating positioning with backboard for data collection.

Discussion

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.[20–23] 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 and groups 2 and 3. There was no difference in the ability to reach between groups 1 and 2, 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.

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Table
Maximal Functional Reach

Subject No.[a]	Maximal Functional Reach (cm)[b]
1	14.10 (5.55)
2	8.48 (3.34)
3	14.61 (5.75)
4	27.53 (10.84)
5	19.91 (7.84)
6	22.12 (8.71)
7	3.40 (1.34)
8	12.70 (5.00)
9	2.54 (3.21)
10	15.04 (5.92)
11	17.78 (7.00)
12	15.77 (6.21)
13	7.62 (3.00)
14	20.32 (8.00)
15	21.39 (8.42)
16	11.63 (4.58)
17	12.93 (5.09)
18	17.35 (6.83)
19	12.80 (5.04)
20	17.48 (6.88)
21	29.12 (11.46)
22	27.31 (10.75)
23	19.91 (7.84)
24	24.03 (9.46)
25	17.15 (6.75)
26	28.37 (11.17)
27	28.37 (11.17)
28	23.93 (9.42)
29	15.24 (6.00)
30	14.71 (5.79)

[a] Group 1 (C5-6 tetreplegia): subjects 1–10; group 2 (T1-4 paraplegia): subjects 11–20; group 3 (T10-12 paraplegia): subjects 21–30.
[b] Measurements in inches shown in parentheses.

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[26] 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.

Conclusion

This study examined the use of the FRT for a population that cannot stand: persons with complete SCI. The modified FRT can become a highly useful test because it is easy and fast to perform and adaptable to many environments. The purpose of this study was to test whether the FRT could provide reliable measurements in persons who are unable to stand. Before the measurements can be shown to be useful, research on their validity is needed.

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