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## Dynamic balance and level of lesion in spinal cord injured patients

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### Summary

This study investigated differences in the dynamic balance of patients with different levels of spinal cord injury (SCI) as well as the intraclass correlation coefficient (ICC) of the modified functional reach test (MFRT). Twenty non-standing Spinal Cord Injured patients (13 males and 7 females) with mean age of 43.15 years (S.D = 10.03 years) participated in the study. They were categorised into three groups based on the level of spinal cord lesion. Group 1 comprised of 8 subjects with C<sub>5</sub>-T<sub>1</sub>, quadriplegia, group 2 comprised of 6 subjects with T<sub>6</sub>-T<sub>8</sub> paraplegia and group 3 comprised of 6 subjects with T<sub>10</sub>-L<sub>1</sub> paraplegia. The dynamic balance of all subjects was assessed using the modified functional reach test. The data were summarized using descriptive statistics of mean and standard deviation with further analysis using ANOVA and Pearson product correlation coefficient. The subjects with paraplegia showed higher functional reach (dynamic balance) than the quadriplegics but there was no significant difference in the functional reach values among the three groups. The ICC for MFRT was high and ranged from 0.981 to 0.992. The result of this study therefore seems to suggest that the MFRT cannot be used to classify patients with different levels of SCI.

**Keywords:** *Modified Functional reach, spinal cord lesion, dynamic balance, measurements, intraclass correlation.*

### Résumé

Cette étude évaluait la différence entre la balance dynamique des patients et la gravité des blessures de la moelle épinière (SCI) aussi bien que la corrélation de coefficient d'interclasses (ICC) des tests modifiés fonctionnels (MFRT). Vingt patients ayant la blessure de la moelle épinière (13 mâles et 7 femelles) avec la moyenne d'âge de 43,15 ans (SD=10,03 ans) étaient recrutées dans cette étude. Ils étaient catégorisés en 3 groupes en fonction de la gravité de la lésion de la moelle épinière. Le premier groupe de 8 sujets avec C<sub>5</sub>-T<sub>1</sub>, quadriplégie; le deuxième groupe de 6 sujets avec T<sub>6</sub>-T<sub>8</sub> paraplégié et le troisième groupe de 6 sujets avec T<sub>10</sub>-L<sub>1</sub> paraplégié. La balance dynamique de tous les sujets était évaluée en utilisant le test modifié fonctionnel. Ces données étaient résumées en utilisant la description statistique moyenne et la déviation standard avec des analyses utilisant l'ANOVA et le coefficient de corrélation de Pearson. Les sujets avec la paraplégie avaient une balance dynamique élevée que chez les tétraplégiques mais il n'y avait pas de différence significative des valeurs fonctionnelles parmi les 3 groupes. Les ICC du MFRT étaient élevés et variaient entre 0,981 à 0,992. Le résultat de cette étude suggère que le test modifié fonctionnel (MFRT) ne peut pas être utilisé pour classer les patients. Ayant différents degrés de lésion de la moelle épinière.

### Introduction

Postural control or balance refers to the maintenance of the body's center of gravity within its base of support during stance or voluntary movement and in response to external perturba-

tions [1]. In normal individuals, visual, vestibular and somatosensory signals are sent to the central nervous system which can adjust body sway and posture by integrating this information and by controlling skeletal muscles to appropriately generate joint torques and adjust joint angles [2]. In spinal cord injured patients however, the neurophysiologic and anatomic components of the postural control system are impaired with resultant difficulties in balance and inhibited functional performance [3,4]. According to Berg *et al* [3] a measure of balance for use with spinal cord injured patients should be comprehensive but reasonably short, not too complicated and safe for use by this patient type. One of such measures is the functional reach test (FRT) designed to measure the limits of stability in anterior direction [5]. The test involves the measurement of the maximal distance that subjects can reach forward while maintaining a fixed base of support. The validity of the test in standing is supported by Stoudt [6] who observed that reaching is a real-world functional volitional movement that constantly imposes a stress to balance.

The FRT was modified by Lynch *et al* [7] to ensure the assessment of anterior and posterior dynamic stability in non-standing subjects. The modified functional reach test (MFRT) thus provides a reliable measurement of balance in sitting. For non-standing persons with SCI, sitting balance tests provide an indication of the subjects ability to maintain balance [7]. The MFRT is a dynamic measure of postural control that is inexpensive, precise, stable, sensitive and clinically accessible.

In view of the fact that non-standing individuals with SCI are challenged more than usual to maintain balance during a variety of functional activities [8], an important aspect of the rehabilitation of these individuals centers around conditioning of balance responses and other interventions to counteract balance deficits. Therefore, a determination of their balance performance in relation to the various levels of lesion would be quite important to physical therapists who as a key member of the health team have to assess the ability of the SCI individuals to perform functional activities required in everyday life in spite of their disability [9]. A study by Lynch *et al* [7] on the reliability of the MFRT in subjects with SCI reported high intraclass correlation coefficient and significant differences in functional reach of subjects with high and low SCI. However, the study was conducted with subjects sitting on a hard surface whereas SCI patients sit most of the time on wheel chairs while carrying out their activities of daily living. Also, all subjects in the study by Lynch *et al* [7] had complete SCI. The purpose of this study therefore was to assess the intraclass correlation coefficient (ICC) of the MFRT and see whether the test can discern between subjects with different levels of SCI.

### Materials and methods

#### Subjects

Twenty (20) non-standing SCI patients (13 male and 7 females) with a mean age of 43.15 ± 10.3 years participated in this study. Subjects were selected through a purposive sampling technique from: the University College Hospital, Ibadan (6 subjects), National Orthopaedic Hospital, Igbobi Lagos (4 subjects) and

Spinal Cord Injury Association of Nigeria, Maryland, Lagos (10 subjects). All the subjects were seen at least 8 weeks into their initial phase of rehabilitation and met the following inclusion criteria as advanced by Lynch *et al* [7]:

1. All subjects were non-standing persons with complete or incomplete spinal cord lesions according to the American Spinal Injury Association (ASIA) impairment scale (10). Non-standing persons were selected so that there would be no lower extremity motor function to allow the subject to weight bear on the feet when reaching forward in sitting.
2. All subjects were able to sit independently on a wheelchair with a backrest.
3. Subjects were excluded by on-site evaluation if they demonstrated less than 90 degrees of shoulder flexion, an elbow flexion contracture or presence of musculoskeletal deformities in the upper extremity used in reaching.
4. Subjects must be able to develop adequate muscle force to maintain shoulder flexion during reaching (as measured by a break test of shoulder flexors) and have adequate range of motion at the shoulder as measured by a goniometer.
5. Certified blind and deaf, non-standing SCI persons were excluded from the study.
6. Spasticity, a common sequela in persons with SCI was not part of the inclusion or exclusion criteria. Spasticity was not measured in any of the subjects.

The subjects were then divided into three groups based on the SCI diagnosis as follows:

Group 1: Subjects with C<sub>5</sub> - T<sub>1</sub> Quadriplegia

Group 2: Subjects with T<sub>6</sub> - T<sub>8</sub> Paraplegia

Group 3: Subjects with T<sub>10</sub> - L<sub>1</sub> Paraplegia

The level and severity (complete or incomplete) of the SCI were based on the report of the orthopaedic or neurosurgeon and confirmed by clinical examination by the researchers. Lesions at lower levels especially cauda equina lesions were excluded since such lesions will cause damage to spinal nerve roots rather than the spinal cord such that the patient may have better functional capacity and potential for recovery

#### Instrumentation

- 1: An inelastic tape measure (Butterfly model, made in China) graduated in centimeters attached to the wall for measurement of functional reach.
- 2: Universal goniometer for measuring range of shoulder motion.
- 3: Wheelchair for subjects to sit in during test.

#### Procedure

Informed consent was obtained from the subjects as soon as they were found to be eligible for the study. Ethical approval was obtained from the UI/UCH Joint Ethical Committee and the authorities of National Orthopedic Hospital Igbobi and Spinal Cord Injury Association Of Nigeria, Lagos before the commencement of data collection. The procedure was then explained to the subjects before the commencement of data collection. Each subject was positioned on the wheelchair and a horizontal straight mark was made along the subject's shoulder at the level of the acromion process. The hips, knees and ankles were positioned at 90 degrees of flexion according to the method of Duncan *et al* [5]. The initial reach which is essentially the length of the subject's upper limb was first determined. The subject was positioned with his back resting against the backrest

of the wheelchair and right upper extremity flexed to 90 degrees parallel to and at the same level with the inelastic tape measure but not touching the wall. The initial reach was measured as the distance between the ulnar styloid process and acromion process of the same upper extremity since the quadriplegic subjects in this study could not make a fist thereby making it impossible to use the third metacarpal originally used in studies of FRT [5,11,12].

For final reach; each subject maximally reached forward as far as he was able to go with the flexed upper extremity without any assistance. After moving to the limits of his ability without loss of balance, measurement was then taken following the format described above. The right upper extremity was the one used for reaching activity [7] and subjects used the non-standing upper extremity for counter balance only (no weight bearing or holding was allowed). The subjects were guarded for safety and the trial was repeated if the subject required assistance to recover to the backrest of the wheelchair.

Each subject had three trials with rest after each trial. The mean of these trials was recorded (7). This represents the maximal functional reach (first trial). Ten minutes after the initial three trials, the whole procedure was repeated and another set of data collected (representing the repeated trial). A single rater collected all data for this study and subjects maintained the same sitting position for each trial to ensure consistency.

#### Treatment of data

The mean and standard deviation of all data were calculated. A one-way analysis of variance (ANOVA) was used to test for difference among the means for reach in the three groups. Test-retest reliability of the FRT was evaluated using intraclass correlation coefficients between the first trial and the repeated trial [13]. Alpha level was set at 0.05.

#### Results

The biodata of subjects are presented in Table 1. Twenty subjects (13 males and 7 females) participated in this study.

Table 1: Biodata of subjects

Group	No. of subjects	% of subjects	Mean duration of SCI (wks)	Min age (yrs)	Max age (yrs)	Mean age (yrs)
1	8	40	128.38 S.D.= 178.44	41	57	46.75 S.D.= 5.65
2	6	30	26.00 S.D.= 20.47	23	65	42.33 S.D.= 15.97
3	6	30	87.37 S.D.= 100.37	28	46	39.17 S.D.= 6.49

Group 1: Subjects with C<sub>5</sub> - T<sub>1</sub> Quadriplegia

Group 2: Subjects with T<sub>6</sub> - T<sub>8</sub> Paraplegia

Group 3: Subjects with T<sub>10</sub> - L<sub>1</sub> Paraplegia

Subject's age ranged from 23 to 65 years with a mean of 43.15 years (SD = 10.03). 8 subjects were in group 1 (C<sub>5</sub> - T<sub>1</sub> Quadriplegia) while 6 subjects each were in groups 2 and 3 (upper and lower paraplegia) respectively. Fourteen (70%) of the subjects had complete spinal cord lesion while only six (30%)

had incomplete spinal cord lesion. Each of the three groups had two subjects with incomplete SCI. The functional reach scores of subjects in the three groups are shown in Table 2. The subjects in group 3 had the highest functional reach. ( $x = 29.47\text{cm}$ ,  $SD = 19.44$  while subjects in group 1 had the lowest ( $x = 13.79\text{cm}$ ,  $SD = 9.73$ ).

**Table 2:** Functional reach scores of subjects in the three groups

Group	Min reach (cm)	Max reach (cm)	Mean $\pm$ S.D.
1	2.70	27.80	13.39 $\pm$ 9.73
2	7.00	41.80	26.77 $\pm$ 13.63
3	8.30	57.50	29.47 $\pm$ 19.44

Group 1: Subjects with C<sub>5</sub> - T<sub>1</sub> Quadriplegia  
 Group 2: Subjects with T<sub>6</sub> - T<sub>8</sub> Paraplegia  
 Group 3: Subjects with T<sub>10</sub> - L<sub>1</sub> Paraplegia

The modified functional reach scores of the subjects in the 3 groups were compared using the one way analysis of variance (ANOVA). The level of significance for the test was  $\alpha = 0.05$ . Analysis showed that there was no significant difference between the modified functional reach scores of the three groups ( $P = 0.115$ ). This is illustrated in table 3. The intraclass correlation coefficients between the first trial and the repeated trial are shown in table 4. These were calculated for all the groups.

**Table 3:** ANOVA table for comparison of modified functional reach of subjects with different levels of SCI

Source of variation	Sun of squares	Degrees of freedom	Mean square	Observed F	Probability	Comment
Between groups	1007.430	2	503.715	2.459	0.115	N.S
Within groups	3483.275	17	204.840			

**Table 4:** Pearson product moment correlation between the first trial and the repeated trial.

	Group 1 n=8	Group 2 n=6	Group 3 n=6
FTVRT	0.989	0.981	0.992

Key: FT = First trial  
 RT = Repeated trial  
 Group 1: Subjects with C<sub>5</sub> - T<sub>1</sub> Quadriplegia  
 Group 2: Subjects with T<sub>6</sub> - T<sub>8</sub> Quadriplegia  
 Group 3: Subjects with T<sub>10</sub> - L<sub>1</sub> Paraplegia

**Discussion**

The result of this study did not show any significant difference between the functional reach scores (dynamic balance) of subjects with different levels of SCI. However the results indicated that the mean functional reach scores (dynamic balance)

increased as the level of SCI became lower. This finding appears to be reasonable because people with lower level paraplegia tend to have greater functional capabilities than people with higher levels of lesion. The subjects with T10-L1 lesion had abdominal and back extensor muscles that were unaffected by their SCI which apparently gave them greater advantage in movement control [7].

The higher mean functional reach in subjects with lower spinal cord lesion in this study was in agreement with that of the study by Lynch *et al* [7]. However, in this study, there were no significant differences between the functional reach of subjects with lower and higher levels of lesion and hence balance ability. This observation may be explained by the wide variations within the groups occasioned probably by the stage of rehabilitation of the subjects. The standard deviations for mean functional reach scores for groups 1, 2 and 3 were 9.73, 13.63 and 19.44 respectively as against 7.6, 4.3 and 5.6 for groups 1 (C5 - C6) group 2 (T1 - T4) and group 3 (T10 - T12) respectively in the study by Lynch *et al* [7]. According to Weiner *et al* [14] the stage of rehabilitation affects the ability to reach forward. Furthermore, the disparity between the results of this study and that of Lynch *et al* (7) may be due to differences in the classification of subjects to groups according to injury level.

The results of this study showed that different levels of SCI have no significant effect on dynamic balance performance of non-standing persons with spinal cord injury. Forward reach in sitting position is a real world functional movement that constantly imposes a stress on balance. The findings of this study showed that non-standing persons with SCI were able to reach forward to various extents depending on the levels of cord lesion in agreement with the submission of Hammell [4] that levels of cord lesion affect functional capabilities of subjects with SCI. Furthermore, the test-retest reliability of the MFRT varied from 0.981 to 0.992. This showed a high reliability of measurement obtained with the MFRT. This is in accordance with the findings of Lynch *et al* [7] who recorded ICC values ranging from 0.85 to 0.94. In addition, the ICC values for test-retest reliability of this study was similar to those documented by previous workers on functional reach studies [5, 11, 12,14].

**Limitations**

The present study was limited by a small sample size occasioned by the stringent inclusion criteria and large variation in the stage of rehabilitation of the SCI subjects. Future studies should hence endeavor to involve large sample size of subjects at comparable levels of rehabilitation. Future studies may also examine the predictive validity of the MFRT..

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