ELSEVIER

JOURNAL OF ORTHOPAEDIC TRANSLATION

ORIGINAL ARTICLE

Reliability of dynamic sitting balance tests and their correlations with functional mobility for wheelchair users with chronic spinal cord injury

CrossMark

Kelly L. Gao [a], K.M. Chan [b], Sheila Purves [a],
William W.N. Tsang [a],*

[a] Department of Rehabilitation Sciences, The Hong Kong Polytechnic University, Hung Hom, Hong Kong
[b] Department of Orthopaedics and Traumatology, The Chinese University of Hong Kong, Shatin, Hong Kong

Summary   The purpose of this study is to develop a reliable and valid tool for measuring the dynamic sitting balance of wheelchair users with spinal cord injury. The balance tests were performed in nine patients with chronic spinal cord injury (average of 17.2 years postinjury) between levels C6 and L1, while they were sitting in their wheelchairs and on a standardized stool (unsupported sitting), twice, 7 days apart. Limits of stability (LOS) and sequential weight shifting (SWS) were designed in this study. The balance tests measured participants' volitional weight shifting in multiple directions within their base of support. Their mobility scores on the Spinal Cord Independence Measure III were correlated with the balance test results. The LOS results showed moderate to excellent test—retest reliability (intraclass correlation coefficients ranged from 0.673 to 0.990) for both the wheelchair and the unsupported sitting. The SWS results showed moderate to excellent reliability (intraclass correlation coefficients ranged from 0.688 to 0.952). The LOS results correlated significantly with the Spinal Cord Independence Measure III mobility scores only in case of unsupported sitting, but the SWS test results showed significant correlations in both sitting conditions. To sum up, the sitting LOS and SWS tests are reliable and valid tools for assessing the dynamic sitting balance control of patients with spinal cord injury.

* Corresponding author. ST502, Department of Rehabilitation Sciences, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong.
   E-mail address: william.tsang@polyu.edu.hk (W.W.N.Tsang).

Introduction

Approximately 70—80% of people with spinal cord injury (SCI) are dependent for life on a wheelchair for mobility [1]. Good sitting balance control is essential for such people because they are often confined to the sitting position when performing the activities of daily living (ADLs). Activities that require sitting quietly (such as feeding, grooming, and bathing), dynamic activities (such as propelling their wheelchair up or down ramps) as well as the ADLs require different degrees of sitting balance control. When ascending a ramp, people with SCI lean forward as far as possible to prevent the wheelchair from tipping backwards. When descending, they lean back as far as possible to prevent falling [2]. These techniques require maximal postural excursions. That is why investigators studying balance control in an SCI population employ maximal postural sway as an outcome measure.

Sitting balance control directly affects transfer performance [3]. An appropriate sitting position is fundamental to providing a stable base of support for transfer activities. A sense of position in space is another crucial factor when attempting a transfer. In addition, the ability to precisely and accurately control intentional movements of the centre of gravity in different directions is important. Better directional control provides more accurate control in performing a variety of transfer activities. When individuals transfer from short sitting (with the hips and knees at approximately 90°) to an unsupported position, they require good directional control. Transfer from a wheelchair to a bathtub is a common example.

Falls are a major problem for SCI sufferers. In a prospective study of 659 community-dwelling wheelchair users who suffered from SCI (age 54.8 ± 12.6 years), 31% reported a total of 553 fall events [4]. In a retrospective study by the same group, a review of 45 individuals with SCI showed that 24 (53%) of them had experienced a total of 27 fall episodes. The major factor contributing to falls was found to be loss of balance during functional activities [5]. Falls most often occurred during transfer (44%), reaching (11%), propelling a wheelchair (15%), moving in bed (22%), transferring to or riding in a vehicle (30%), and taking a shower (8%). Wheelchair users with SCI have been found to have decreased or absent trunk control, leading to poor sitting balance and stability, which in turn may cause falls during transfer [6].

A supported or unsupported short sitting position is commonly adopted by people with SCI when performing the ADLs. However, most previous studies assessing sitting balance control have focused on the maximum displacement of the centre of pressure (COP) when sitting with knees straight, which are relatively less functional. In addition, the assessment of sitting balance control should include the diagonal movements commonly required in transfer. The time and movement control required to achieve different excursions have not been investigated in previous studies, but they are important factors in dynamic sitting balance control. When performing transfer activities, people with SCI usually lean the trunk forward to lift their buttocks off the initial surface and quickly pivot the buttocks to the target surface using a twisting motion [7]. Moreover, the functional activities do not end in a single direction, but in a sequence of movements. The present study was therefore designed to develop laboratory-based tests for use in a clinical setting to assess the dynamic sitting balance control of wheelchair users with SCI.

Materials and methods

Nine persons with SCI participated in this study—six females and three males (refer to Table 1). The participants were aged 35—63 years (mean $\pm$ standard deviation, 50.6 ± 10.7 years). Time since injury averaged 17.2 years (from 2 years to 48 years). Their level of injury ranged from C6 to L1, according to the International Standards for Neurological and Functional Classification of SCI. One year postinjury is commonly classified as the chronic stage because neural recovery plateaus at approximately 12 months postinjury [8]. The inclusion criteria for the study were as follows: able to sit unsupported; at least 1 year postinjury; incomplete injury according to the American Spinal Injury Association Impairment Scale; aged $\geq$18 years; and able to communicate and follow instructions. The exclusion criteria were the following: unstable cardiopulmonary disease; serious complications related to the SCI, such as pressure ulcers; contracture or marked hypertonicity of the muscles; poorly controlled hypertension; and metastatic cancer. Written consent was obtained from all participants prior to the start of the study. The study was approved by the Ethics Committee of the Hong Kong Polytechnic University, Hung Hom, Hong Kong (HSEARS09902245R). All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2000.

Testing procedure

Two dynamic sitting balance control tests were conducted—limits of stability (LOS) test and sequential weight shifting test. The two tests were performed in patients either in supported or unsupported sitting conditions.

Instrumentation

The setup consisted of a tailor-made force platform (90 cm × 90 cm) and an adjustable-height screen placed

Table 1 Characteristics of the participants.

Participant	Age (y)	Time since injury (y)	Injury level	ASIA grade
1	35	22	T1	B
2	36	10	T1	B
3	57	11	T1	B
4	63	48	T1	C
5	61	2	T1	C
6	58	13	L1	D
7	55	10	C7	D
8	48	10	T12	D
9	42	29	C6	B

ASIA = American Spinal Injury Association.