Clin Biomech (Bristol, Avon). Author manuscript; available in PMC 2012 October 15.

Published in final edited form as:
Clin Biomech (Bristol, Avon). 2002 August ; 17(7): 555–557.

Multidirectional measures of seated postural stability

Heather M Kerr, PT[1,3] and **Janice J Eng, PhD, PT/OT**[2,3,*]

[1]Riverfront Physiotherapy, Whitehorse, Yukon, Canada

[2]Department of Physical Therapy, University of BC, Vancouver, BC, Canada

[3]Rehabilitation Research Laboratory, GF Strong Rehab Centre, Vancouver, BC, Canada

Abstract

Objective—To quantify the limits of stability during a leaning/reaching task and determine 1) test-retest reliability and 2) effect of movement direction and foot support.

Design—Test-retest reliability design.

Background—Seated reaching and leaning are used in rehabilitation programs to assess and train sitting balance and motor function. Continuous (as opposed to ordinal), multidirectional measures of seated postural stability have not been previously presented.

Methods—12 older adults performed a seated reaching/leaning task while net body centre of pressure displacement and velocity were measured with three forceplates (under buttocks and each foot) over two separate days. Conditions of movement direction (forward, backward, lateral) and foot support (with and without) were randomized.

Results—Except for the backward movement in the supported foot condition, all measures had moderate to very high reliability. Measurements were sensitive to both foot support and movement direction.

Keywords

postural control; forceplate; sitting balance; reliability

INTRODUCTION

Postural stability is the ability to maintain the center of mass (CoM) within specific boundaries of space (i.e., stability limits).[1] Sitting postural stability may reduce the risk of falls[2], decrease the need for specialized seating and facilitate interaction with one's environment. Current measures of sitting postural stability use ordinal scales[3–5] which may lack the ability to discriminate change[3]. In contrast, the Modified Functional Reach Test is a continuous measure of forward seated reaching with established reliability and face validity in subjects with spinal cord injury.[6] Nichols et al.[7] measured forces under the buttocks

Corresponding Author: Janice Eng, PhD, PT/OT, Professor, Department of Physical Therapy, University of British Columbia, 212-2177 Wesbrook Mall, Vancouver, BC, Canada, V6T 1Z3 Tel: (604) 714-4105, fax: (604) 714-4168, Janice.Eng@ubc.ca.

Relevance
Centre of pressure measures provide reliable measures which may be useful for clinical assessment of seated postural stability.

during seated leaning movements, however, this measure does not represent whole body postural control since the forces through the subjects' feet are not accounted for.

Ideally, a measurement of sitting postural stability should account for multidirectionality and foot support, as these factors influence sitting balance.[8,9] Thus, the purpose of this study was to: 1) determine test-retest reliability and 2) quantify the effect of movement direction and foot support for a seated leaning/reaching task using centre of pressure (CoP) measures.

METHODS

The participants were twelve healthy older adults (five men, seven women), mean age of 64.9 (SD 4.2) years, height of 166.0 (SD 8.7) cm and mass of 73.5 (SD 13.9) kg. Two test sessions were separated by two to four days. Subjects were seated on a forceplate attached to a height-adjustable bench with eighty percent of the thigh supported. They were instructed to 1) reach forwards using both hands, 2) reach to the side using left/right hand, and 3) lean backward, both hands in your lap. Subjects were to move as far and fast as possible and hold the terminal position for three seconds. Conditions of movement direction and foot support (supported foot condition [SFC] with hips/knees at 90° and feet on two forceplates and unsupported foot condition [UFC] with a raised seat height and feet dangling) were randomized and a total of five trials for each condition collected.

Force plate data were sampled at 600 Hz for six seconds and custom software was used to calculate the net CoP (derived from three forceplates for SFC) and identify the maximal CoP displacement and average velocity. Statistical analyses were performed on the mean absolute values but both absolute and normalized values (to upper body length) are presented in Table 2. Intraclass correlation coefficients (ICCs) and the standard error of the measurement (SEM) were used to assess relative and absolute reliability, respectively, between the two test sessions.

Two factor (movement direction and foot support) ANOVAs blocked for subject were used to assess effects on the CoP displacement and velocity followed by Tukey's post-hoc (SPSS 9.0 for Windows, α=0.05).

RESULTS

Except for the SFC backward CoP displacement, ICCs for the measures were moderate to very high (0.64–0.94) and absolute reliability was within 3.9–9.9% of the original measurement (Table 1). For further analyses, the two test sessions were averaged.

There was a significant interaction of movement direction and support condition. The post-hoc analyses found that both CoP displacement and velocity were significantly greater by 120% in the SFC forward movement compared to other directions. There was no direction effect for the CoP displacement for the UFC, however, the forward and dominant side CoP velocity were significantly greater by 10 and 18%, respectively, compared to the backward and non-dominant CoP velocity in the UFC.

Foot support significantly reduced CoP displacement (but not velocity) by 20% in the lateral and backwards direction compared to the UFC. In contrast, foot support increased CoP displacement and velocity by over 70% in the forward direction compared to the UFC.

DISCUSSION

The test-retest reliability indicates that CoP measures of multidirectional seated postural stability may be useful as a clinical measure and further studies should evaluate the validity of these measures, particularly in individuals with difficulties with sitting balance. The poor reliability for the backward displacement in the SFC may be attributed to unfamiliarity of this particular task.

Seated postural stability was influenced both by movement direction and foot support. Stability limits were greatest in the forward SFC compared to other directions because the supported feet effectively extend the base of support. CoP velocity measures were sensitive to differences between the dominant and non-dominant sides. Interestingly, although subjects move farther in the lateral and backward UFC compared to their respective SFC, the velocity was not different between support conditions for these directions. The general definition of postural stability[1] takes only spatial limits into account, whereas the present results suggest that velocity is an important consideration as well.

Foot support and movement direction both influence the seated limits of stability and these factors should be considerations in assessment and rehabilitation of sitting balance, and also in design of wheelchair and seating devices.

Acknowledgments

The authors wish to acknowledge the support of the BC Health Research Foundation, the BC Medical Services Foundation, the Rick Hansen Neurotrauma Initiative, and the Canadian Institute of Health Research (operating grant # 57862).

References

1. Shumway-Cook, A., Woollacott, MH. Motor control: Theory and Applications. Baltimore, MD: Williams and Wilkins; 1995. p. 120-122.
2. Cheng PT, Liaw MY, Wong MK, Tang FT, Lee MY, Lin PS. The sit-to-stand movement in stroke patients and its correlation with falling. Arch Phys Med Rehabil. 1998; 79:1043–1046. [PubMed: 9749681]
3. Sandin KJ, Smith BS. The measure of balance in sitting in stroke rehabilitation prognosis. Stroke. 1990; 21:82–86. [PubMed: 2300995]
4. Black K, Zafonte R, Millis S, Desantis N, Harrison-Felix C, Wood D, Mann N. Sitting balance following brain injury: does it predict outcome? Brain Injury. 2000; 14:141–152. [PubMed: 10695570]
5. Swaine BR, Sullivan SJ. Reliability of early motor function testing in persons following severe traumatic brain injury. Brain Injury. 1996; 10:263–276. [PubMed: 9044692]
6. 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. [PubMed: 9474105]
7. Nichols DS, Miller L, Colby LA, Pease WS. Sitting balance: its relation to function in individuals with hemiparesis. Arch Phys Med Rehabil. 1996; 77:865–869. [PubMed: 8822675]

8. Chari VR, Kirby RL. Lower-limb influence on sitting balance while reaching forward. Arch Med Phys Rehabil. 1986; 67:730–733.
9. Crosbie J, Shepherd RB, Squire TJ. Postural and voluntary movement during reaching in sitting: the role of the lower limbs. J Human Movement Studies. 1995; 28:103–126.

Table 1

Intraclass correlations and standard error of the measurement (SEM)[a] for centre of pressure (CoP) displacement and velocity (N = 12).

	CoP Displacement		CoP Velocity	
Movement Direction	**Supported foot**	**Unsupported foot**	**Supported foot**	**Unsupported foot**
Dominant side	0.82 (0.40)	0.74 (0.83)	0.80 (0.70)	0.86 (0.94)
Non-Dominant side	0.64 (0.77)	0.83 (0.81)	0.80 (0.83)	0.90 (1.14)
Forward	0.81 (2.27)	0.90 (0.75)	0.92 (2.25)	0.93 (1.13)
Backward	0.39 (2.19)	0.94 (1.12)	0.76 (1.46)	0.86 (1.37)

[a]SEM in parentheses (cm for CoP displacement and cm/sec for CoP velocity)

Table 2

Mean centre of pressure (CoP) displacement (cm) and velocity (cm/sec) and corresponding normalized values[a] for the foot supported and unsupported conditions in each movement direction. (N = 12).

Movement Direction	Supported foot Absolute	Supported foot Normalized	Unsupported foot Absolute	Unsupported foot Normalized
CoP displacement				
Dominant side	10.19 (0.93)[b]	12.3 (1.02)	12.59 (1.47)	15.14 (1.65)
Non-Dominant side	10.26 (1.40)	12.32 (1.44)	12.32 (1.90)	14.81 (2.16)
Forward	22.96 (5.37)	27.52 (5.71)	13.20 (2.52)	15.85 (2.77)
Backward	10.30 (2.71)	12.44 (3.37)	13.28 (4.33)	16.06 (5.42)
CoP velocity				
Dominant side	11.42 (1.54)	13.75 (1.94)	12.65 (3.74)	15.16 (4.22)
Non-Dominant side	10.98 (1.65)	13.31 (1.95)	11.32 (2.44)	13.72 (2.91)
Forward	24.36 (7.37)	29.52 (8.60)	13.59 (4.98)	16.25 (5.45)
Backward	9.55 (2.75)	11.61 (3.45)	11.52 (3.52)	13.80 (3.87)

[a] normalized to upper body length (greater trochanter to top of head in cm) × 100

[b] standard deviation in parentheses