ACRM
AMERICAN CONGRESS OF REHABILITATION MEDICINE

Archives of Physical Medicine and Rehabilitation

journal homepage: www.archives-pmr.org

Archives of Physical Medicine and Rehabilitation 2014;95:65-73

ORIGINAL ARTICLE

Estimating Postural Control With the Balance Rehabilitation Unit: Measurement Consistency, Accuracy, Validity, and Comparison With Dynamic Posturography

Khalid A. Alahmari, PT, PhD,[a] Gregory F. Marchetti, PT, PhD,[b,c] Patrick J. Sparto, PT, PhD,[a,c] Joseph M. Furman, MD, PhD,[a,c] Susan L. Whitney, PT, PhD[a,c]

From the [a]Department of Physical Therapy, University of Pittsburgh, Pittsburgh, PA; [b]Department of Physical Therapy, Duquesne University, Pittsburgh, PA; and [c]Department of Otolaryngology, University of Pittsburgh, Pittsburgh, PA.

Abstract

Objective: To examine the psychometric properties (test-retest reliability, concurrent validity, construct validity) of the Balance Rehabilitation Unit (BRU) during testing of sensory integration processes in healthy adults and individuals with vestibular disorders.

Design: Experimental cross-sectional design.

Setting: Clinic.

Participants: Participants (N=90) included 30 subjects with vestibular disorders (age range, 18−85y), 30 young healthy adults (age range, 18−50y), and 30 older healthy adults (age range, 60−85y).

Interventions: Not applicable.

Main Outcome Measures: Participants were tested twice with the BRU and once with the SMART EquiTest Sensory Organization Test (SOT). The center of pressure (COP) in the anteroposterior direction (COP_{ap}) and the COP in the mediolateral direction (COP_{ml}) were recorded. The COP_{ap} and COP_{ml} time series were used to estimate the area and velocity of the COP.

Results: The intraclass correlation coefficient of the COP area and velocity measures for the BRU for all subjects was at least .76 in all sensory organization conditions ($P<.001$). Significant correlations were found between the BRU and the SOT, ranging from .64 to .81 for COP area and from .44 to .76 for COP velocity. The older control group had significantly greater COP area and velocity compared with younger controls for the BRU and the SOT. The COP (area, velocity) was significantly higher for the younger individuals in the vestibular group than the younger controls.

Conclusions: The reliability and validity of COP measurements obtained during testing of the sensory integration processes were demonstrated using the BRU. Future work should examine the responsiveness of these measures when individuals with balance disorders participate in rehabilitation.

Archives of Physical Medicine and Rehabilitation 2014;95:65-73

Individuals with vestibular disorders and older adults have a higher risk for falling compared with younger, healthy adults.[1,2] Many risk factors for falls are associated with decreased sensory function, including reduced visual, vestibular, and somatosensory function.[3-6] Measuring the effect of sensory feedback on postural control during standing has been investigated using numerous clinical and experimental methods. Shumway-Cook and Horak[7] described the use of a sensory conflict dome and foam to provide a head-fixed visual environment and inaccurate somatosensory feedback. The test paradigm was called the Clinical Test of Sensory Integration on Balance (CTSIB). The foam provides destabilization in conditions 4, 5, and 6; the dome provides a head-fixed visual reference in conditions 3 and 6. Methods of testing the sensory control of balance have also been developed using

Supported by the University of Pittsburgh and King Khalid University.

No commercial party having a direct financial interest in the results of the research supporting this article has conferred or will confer a benefit on the authors or on any organization with which the authors are associated.

0003-9993/14/$36 - see front matter © 2014 by the American Congress of Rehabilitation Medicine
http://dx.doi.org/10.1016/j.apmr.2013.09.011

computerized dynamic posturography, such as the EquiTest Sensory Organization Test (SOT), which uses a tilting floor and moving walls to provide inaccurate somatosensory and visual sway-referenced feedback during standing. Tilting of the walls and floor provides sensory destabilization in the sagittal plane resulting in increased sway in the anteroposterior (AP) direction. The SOT has been used in many clinical and experimental investigations of balance control.[8-11]

The difference between the use of a foam pad versus a tilting floor to provide inaccurate somatosensory feedback has been studied. El-Kashlan et al[12] found that the total time spent in all stance conditions of the CTSIB were significantly correlated with the summed equilibrium scores of the SOT conditions. However, correlations for individual conditions were not reported. Allum et al[13] compared the amount of sway associated with standing on a foam pad with eyes open and closed with standing on a platform tilting in the AP or mediolateral (ML) direction with eyes open and closed. Greater trunk sway in the AP direction was induced by the EquiTest platform when subjects had their eyes closed with AP sway-referencing compared with standing on foam. On the contrary, less trunk sway velocity in the ML direction was observed with AP sway-referencing than with foam. Postural responses have greater AP and ML symmetry when using foam compared with the AP sway-referencing provided by the EquiTest platform. Virtual reality and gaming technologies are being used for balance assessment and rehabilitation.[14-16] It is likely that these systems can be used for the evaluation of an individual's use of sensory feedback for balance control. Rather than using a visual conflict dome for assessing the influence of visual feedback on balance, head-mounted displays (HMDs) can be used to provide head-fixed visual stimuli.[17,18] The Balance Rehabilitation Unit (BRU) is one such system that uses an HMD and foam in order to test the sensory contributions to balance.[19-21] However, before these types of systems are used clinically, a thorough evaluation of the reliability and validity of their measurements should be conducted. The aims of this study are (1) to examine the test-retest reliability of the BRU in young healthy, older healthy, and individuals with vestibular disorders; (2) to examine the concurrent validity of the BRU compared with the SOT; and (3) to examine the construct known-groups validity by investigating the effects of age and disease on balance performance using the BRU.

Methods

Design

The study is an experimental, cross-sectional design. Each subject was tested twice using the BRU[a] and once using the SOT during the same visit. Subjects were given a 15-minute break after each test with the BRU and the SOT. To minimize the order-effect bias, the order of testing of the 2 systems was changed with every other subject (BRU 1, BRU 2, SOT; SOT, BRU 1, BRU 2). For both systems, every subject performed 3 trials of 6 conditions; each trial lasted for 20 seconds.

List of abbreviations:

AP	**anteroposterior**
BRU	**Balance Rehabilitation Unit**
COP	**center of pressure**
COP_{ap}	**center of pressure in the anteroposterior direction**
COP_{ml}	**center of pressure in the mediolateral direction**
CTSIB	**Clinical Test of Sensory Integration on Balance**
HMD	**head-mounted display**
ICC	**intraclass correlation coefficient**
MDC_{95}	**minimal detectable change at the 95% confidence level**
MDC%	**minimal detectable change proportion**
ML	**mediolateral**
SOT	**Sensory Organization Test**

Participants

The study protocol was approved by the University of Pittsburgh Institutional Review Board, and all subjects provided informed consent. The study included 90 subjects: 30 subjects between the ages of 18 and 85 years with vestibular disorders with diagnoses confirmed by a neurotologist; 30 young healthy controls between the ages of 18 and 50 years; and 30 older healthy controls between the ages of 60 and 85 years. The control subjects were recruited through local advertisements and from previous balance research studies. The sample size estimate was based on an effect size (Cohen d) of .75 between older and younger subjects from previously collected posturography data.[22]

Exclusion criteria for all subjects included known pregnancy and the use of assistive devices for standing. For the healthy control subjects, exclusion criteria included symptoms of inner ear disorders, such as complaints of dizziness, vertigo, or balance problems. Healthy controls were screened before testing to confirm that subjects did not have vestibular disorders. Exclusion criteria for controls included the following: (1) observation of spontaneous nystagmus, (2) abnormal ocular motor function, (3) a positive Dix-Hallpike or roll test for benign paroxysmal positional vertigo, or (4) a positive horizontal head shake test or head thrust test. Vestibular disorder diagnosis and vestibular laboratory test results (ocular motor testing, positional testing, caloric testing, rotational chair testing, and cervical vestibular-evoked myogenic potentials) were retrieved from the patients' medical records. Demographic and clinical information of all subjects, including age, sex, duration of symptoms, location of dysfunction, and laboratory tests for patients, are presented in table 1.

Assessment systems

The BRU consists of a force platform, HMD, overhead safety harness, and a foam cushion. The BRU measures the area of a 95% confidence ellipse of the center of pressure (COP) excursion in the AP and ML directions and the average velocity of the COP during 6 different conditions that assess the same sensory integration abilities as the SOT and CTSIB, including condition 1 (standing on a firm surface with eyes open, without using the HMD), condition 2 (standing on a firm surface with eyes closed), condition 3 (standing on a firm surface viewing a stationary visual scene [basketball gym] displayed in the HMD), condition 4 (standing on foam with eyes open without using the HMD), condition 5 (standing on foam with eyes closed), and condition 6 (standing on foam viewing a stationary visual scene displayed in the HMD). In a similar fashion to the SOT conditions, in conditions 3 and 6 the head-fixed visual environment moves with the subject, providing visual sway-referencing. In conditions 4, 5, and 6, the foam surface distorts the normative reference to the ground sensed by lower extremity somatosensation.