Archives of Physical Medicine and Rehabilitation

journal homepage: www.archives-pmr.org

Archives of Physical Medicine and Rehabilitation 2015;96:331-9

ORIGINAL ARTICLE

Postural Control in Response to Altered Sensory Conditions in Persons With Dysvascular and Traumatic Transtibial Amputation

Prasath Jayakaran, PhD, Gillian M. Johnson, PhD, S. John Sullivan, PhD

From the Centre for Health, Activity, and Rehabilitation Research, University of Otago, Dunedin, New Zealand.

Abstract

Objective: To compare the postural control of persons with a dysvascular transtibial amputation and traumatic transtibial amputation with able-bodied adults with and without a dysvascular condition in altered sensory testing conditions.

Design: Cross-sectional study.

Setting: University balance clinic.

Participants: The study participants (N=35) included: participants with a dysvascular transtibial amputation (n=9), participants with a traumatic transtibial amputation (n=9), age-matched able-bodied adults without a dysvascular condition (n=9), and able-bodied adults with a dysvascular condition (n=8).

Interventions: Six Sensory Organization Test (SOT) conditions, which included standing with eyes open (condition 1) and closed (condition 2) on a static force platform with visual surround; standing with eyes open on a static force platform with movable visual surround (condition 3); standing with eyes open (condition 4) and closed (condition 5) on a movable force platform with static visual surround; and standing with eyes open on a movable force platform with movable visual surround (condition 6).

Main Outcome Measures: Bilateral anteroposterior (AP) and mediolateral (ML) center of pressure variables, namely root mean square distance (RMSD) and mean velocity (mVel), for each of the 6 SOT conditions.

Results: The dysvascular transtibial amputation group demonstrated a higher AP RMSD ($P \leq .04$) on the sound side than did the able-bodied adults without a dysvascular condition and the able-bodied adults with a dysvascular condition in SOT conditions 1 and 2, respectively. Both the dysvascular transtibial amputation group and the traumatic transtibial amputation group demonstrated a higher AP RMSD ($P \leq .002$) than the able-bodied adults without a dysvascular condition in SOT conditions 3 and 4. The dysvascular transtibial amputation group showed higher AP mVel ($P \leq .002$) on the sound side for SOT conditions 2 and 3, whereas both amputation groups showed higher AP mVel for SOT conditions 1 and 4 than the able-bodied adults with and without a dysvascular condition.

Conclusions: Postural control of the dysvascular transtibial amputation group was not different than the traumatic transtibial amputation group in challenging sensory conditions. However, when compared with the groups of able-bodied adults with and without a dysvascular condition, postural strategies distinct with amputation etiology were observed.

Archives of Physical Medicine and Rehabilitation 2015;96:331-9

The 3 peripheral sensory sources that play a key role in postural control are vision, vestibular system, and somatosensory system.[1] In persons with a lower-limb amputation, the somatosensory system is compromised because of the absence of at least a normative foot, ankle, and the surrounding muscles/ligaments.[2,3] Additionally, pressure from the residual limb−prosthetic socket interface may be a new source of sensory stimuli to the central nervous system.[4,5] Persons with a limb amputation secondary to complications arising from peripheral vascular disease and/or diabetes (dysvascular) have more limitations in their daily functioning than persons with amputation because of another etiology.[6] It is recognized in persons without an amputation that the decline in sensory function because of a dysvascular condition affects sensory organization and postural control.[7-9] Therefore, it is likely

Supported by the New Zealand Artificial Limb Service, Wellington (grant no. PL10674001PLX).

Disclosures: none.

0003-9993/14/$36 - see front matter © 2015 by the American Congress of Rehabilitation Medicine
http://dx.doi.org/10.1016/j.apmr.2014.09.037

that these postural responses are amplified in persons with a dysvascular limb amputation.

Generally, persons with a lower-limb amputation have an augmented dependence on vision in static conditions,[10-12] which suggests a compensatory mechanism underpinning the disruption of somatosensory input. Although persons with a transtibial amputation may adapt to changes in the somatosensory system,[13] the relative roles of the 3 sensory systems are unknown.

The compensatory sensory organization strategies in postural control have been studied in other clinical populations using the Sensory Organization Test (SOT), which manipulates the recruitment of the peripheral sensory information (vision/vestibular/somatosensory) with 6 different testing conditions.[14,15]

Two cross-sectional investigations in persons with amputation[16,17] have previously used the SOT. Nonetheless, the studies' focus was directed toward comparing the effect of different prosthetic components on postural control[16] or in identifying frequent fallers,[17] and these studies did not aim to discuss the possible sensory reorganization of postural control. Although a recent longitudinal study investigated sensory organization using the SOT in transtibial amputation,[18] the possible differences in organization between dysvascular amputation and amputation of other etiologies was not explored.

Therefore, the purpose of the current study was to compare postural control between persons with a dysvascular amputation and traumatic amputation with that of age-matched able-bodied adults with and without a dysvascular condition. On the basis of additional sensory compromise in the dysvascular transtibial amputation group, it was hypothesized that postural control of the dysvascular transtibial amputation group would be different from that of the traumatic transtibial amputation group and that of the able-bodied adults with and without dysvascular conditions, particularly in the dynamic sensory testing conditions.

Methods

Participants

Men and women aged $\geq$45 years with a unilateral transtibial amputation caused by a dysvascular condition or trauma and age-matched control subjects with and without a dysvascular condition were sought. Participants for the dysvascular transtibial amputation and traumatic transtibial amputation groups were identified from the New Zealand Artificial Limb Service database and were invited to participate in the study. The inclusion criteria for amputation participants were as follows: regular users of the prosthesis; able to stand and walk independently without walking aids; and free from skin lesions, open wounds, phantom limb sensation, and/or pain.

Age-matched participants for able-bodied adults with a dysvascular condition group were recruited from a weekly exercise group that was run by the school of physiotherapy for people with dysvascular disease. The participants for the able-bodied adults group were recruited from the local community. The only inclusion criterion for the able-bodied adult groups was ability to stand and walk independently without walking aids.

The exclusion criteria for all 4 groups were presence of a known neurologic disorder, vestibular problems resulting in periods of dizziness and loss of balance, marked visual impairment (self-declared), impaired cognitive function, history of recent trauma, fracture, surgeries to the lower limb, and/or hip/knee arthroplasty. Participants were not advised to abstain from or modify their regular medication at the time of testing. The study was approved by the University of Otago Human Ethics Committee, and all participants provided written informed consent prior to their participation.

List of abbreviations:

AP	**anteroposterior**
COP	**center of pressure**
ML	**mediolateral**
mVel	**mean velocity**
RMSD	**root mean square distance**
SOT	**Sensory Organization Test**

Setting and equipment

The study was undertaken in the school of physiotherapy balance clinic. The SOT was administered using the SMART EquiTest version 8.4.0,[a] which consists of two 22.86cm $\times$ 45.72cm force platforms supported by 5 force transducers mounted on a servo-motored movable platform base.[19] The study protocol was designed using the research module of the EquiTest system to allow auto-randomization of the testing order, without altering the original constructs of the SOT. Data were acquired at a sampling rate of 100Hz.

Tasks

The 6 sensory testing conditions of the SOT are illustrated in figure 1. Condition 1 is standing on a static platform when all 3 sensory inputs are available, whereas condition 2 is standing with eyes closed on a static platform. In condition 3, the visual input is manipulated with a sway-referenced movable visual surround when standing with eyes open. The somatosensory input is manipulated in conditions 4 and 5 with a sway-referenced movable platform, in eyes open and closed situations, respectively; condition 6 is tested with a sway-referenced movable platform and visual surround in the eyes open condition. Sway reference is defined as movement of a platform and/or visual surround with reference to the individual's anteroposterior (AP) sway. The description of the SOT construct and the sensory system challenged in each condition is detailed elsewhere.[20]

Outcome measures

The root mean square distance (RMSD) and mean velocity (mVel) measures in the AP and mediolateral (ML) directions, derived from the 20-second center of pressure (COP) sway recordings for each of the 6 SOT conditions, were of interest in this study. The RMSD is considered to be a reflection of the ability of the postural control system to achieve a stable posture, where the greater the RMSD, the less the stability, and vice versa.[21] The mVel is reflective of the ability to control the sway; where higher mVel signifies greater difficulty in maintaining postural control.[21] Because motor control varies significantly between the prosthetic and sound limb in persons with amputation,[22] the measures derived for each foot (sound/prosthetic side for amputation groups; left and right side for able-bodied adults and able-bodied adults with a dysvascular condition groups) were considered for all 6 sensory testing conditions.

Reliability of SOT COP measures is yet to be investigated in persons with and without amputations. However, the equilibrium and strategy scores of the SOT as determined by EquiTest software have acceptable test-retest reliability[23] and concurrent validity[24] in