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Original Research

Weight Symmetry and Latency Scores for Unexpected Surface Perturbations in Subjects With Traumatic and Vascular Unilateral Transtibial Amputation

Francisco Molina-Rueda, BcPT, MSc, PhD, Alberto Molero-Sánchez, MD, MSc, Isabel M. Alguacil-Diego, MD, PhD, María Carratalá-Tejada, BcPT, MSc, Alicia Cuesta-Gómez, BcPT, MSc, Juan Carlos Miangolarra-Page, MD, PhD

Abstract

Background: Subjects with lower limb amputation develop new motor control strategies to preserve balance when they experience unexpected perturbations. Most studies performed thus far have not aimed to discuss the possible differences in postural control between subjects with vascular unilateral transtibial amputation (UTA) and subjects with traumatic UTA.
Objective: To analyze the automatic postural reaction in response to unexpected surface perturbations in a sample of subjects with traumatic and vascular UTA and to compare these observations with those for a group of healthy subjects.
Setting: University department.
Design: Observational study.
Participants: A total of 9 men with traumatic UTA, 7 men with vascular UTA, and 10 control subjects without amputation.
Intervention: Computerized dynamic posturography Smart EquiTest System version 8.0 was used to measure automatic postural responses in both groups.
Main Outcome Measures: The motor control test was used to assess the participants' automatic postural responses to unexpected surface perturbations.
Results: Latency scores showed that subjects with traumatic UTA coped with faster latencies under their sound limb than did the subjects with vascular UTA in medium backward and forward perturbations (medium-backward: $P = .004$; medium-forward: $P = .037$). In addition, the subjects with traumatic UTA also managed faster responses to medium-backward ($P = .017$ versus right control limb; $P = .046$ versus left control limb) and large-backward ($P = .021$ versus right control limb) and medium-forward ($P = .012$ versus right control limb; $P = .043$ versus left control limb) perturbations in their sound limb in contrast to control subjects. Weight symmetry showed that the subjects with traumatic UTA bore significantly more weight through their sound limb compared with the control subjects during medium and large backward translations ($P = .028$ and $P = .045$, respectively).
Conclusions: The subjects with traumatic UTA had a greater reliance on their sound limb, and they had faster latencies and more weight in the sound limb upon experiencing unexpected perturbations compared with the control subjects. Conversely, persons with vascular UTA experienced slower latency responses in the sound limb compared with persons with traumatic UTA.

Introduction

When an unexpected surface perturbation is experienced, automatic postural reactions (or postural reflexes) are initiated to maintain upright stability [1,2]. As a result of the lower limb amputation, the afferent nerve pathways from lower limb are affected, and a decreased amount of somatosensory information is available to the central nervous system [3,4]. The amputation leads to a reduction in joint mobility, muscle strength, and ability to actively adjust prosthetic behavior during perturbed stance [3-6].

Under these circumstances, it is recognized that subjects with lower limb amputation develop new motor control strategies to preserve balance [7-12]. Several studies have analyzed postural control on a platform that moved in the anteroposterior direction. The focus of these studies was directed toward comparing the

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effect of different conditions (eyes open, blindfolded, and while performing a dual task) on postural control [13-15] or identifying the differences in postural control between amputee fallers and amputee nonfallers [16]. These studies did not aim to discuss the possible differences in postural control between subjects with vascular unilateral transtibial amputation (UTA) and subjects with traumatic UTA. Therefore, the possible differences in response to unexpected perturbations between subjects with vascular UTA and subjects with traumatic UTA were not explored. However, it is known that persons with a lower limb amputation as a result of vascular disease have more restrictions in their activities of daily living than do subjects who have had an amputation for another reason [17,18].

Understanding how subjects with amputation respond to unexpected perturbations could have important implications for their rehabilitation because subjects with vascular and traumatic transtibial amputation should not be considered as a single entity in rehabilitation programs [19].

The aim of this study was to analyze the automatic postural reaction in response to unexpected surface perturbations in subjects with traumatic and vascular UTA and to compare these observations with those of a group of control subjects.

Methods

Participants

Subjects were selected via consecutive nonprobabilistic sampling. Nine men with traumatic UTA (5 right amputees and 4 left amputees; age range, 37-67 years) and 7 men with vascular UTA (3 right amputees and 4 left amputees; age range, 39-68 years) who used a permanent prosthesis participated through various local associations, private clinics, and hospitals. Ten men without amputation served as a control group (age range, 46-61 years). Control subjects were recruited for participation via fliers on campus. The inclusion criteria for subjects with amputation were as follows: agreement with and signature of an informed consent form by the subject, 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. The inclusion criteria for the control subjects included walking independently without assistive devices and the absence of musculoskeletal and neurologic disorders. The exclusion criteria for all 3 groups were presence of a known neurologic disorder, vestibular problems, marked visual deficiency, impaired cognitive function, history of recent trauma, peripheral arterial disease affecting the lower limbs, fractures, and surgeries to the lower limb.

All of the subjects wore total surface bearing prostheses with pin suspension. Table 1 shows the types of prostheses worn. Prosthesis alignment was established clinically, with each fitting assessed and optimized by a team of 2 certified prosthetists. All participants were considered stable in their prosthetic adjustment. Table 2 shows the characteristics of subjects with UTA and control subjects.

Table 1
Type of prosthetic feet

Etiology	Type of Prosthetic Feet
Traumatic	Ceterus
	Vari-Flex
	Multi-axis foot
	Flex-Foot (3)
	SACH
	Trias
	Talux
Vascular	Flex-Foot (2)
	Sure-Flex
	Ceterus
	SACH
	Triton
	Vari-Flex

Ethical Aspects

All participants provided a written informed consent prior to participation in this investigation, which was approved by the Ethics Committee at Rey Juan Carlos University (Madrid, Spain) and warranted its accordance with the Declaration of Helsinki.

Procedure

The computerized dynamic posturography Smart EquiTest System version 8.0 (NeuroCom International Inc, Clackamas, OR) was used for measuring the automatic responses to unexpected surface perturbations in both groups. The study was conducted at the Motion Analysis, Ergonomics, Biomechanics, and Motor Control Laboratory at Rey Juan Carlos University.

The Smart EquiTest is composed of a steel frame incorporating a dual-force plate system. Each force plate is 23 by 46 cm, and the 2 force plates are connected by a pin joint. Force is measured by 4 transducers mounted symmetrically on a central plate, with a fifth transducer bracketed to the central plate below the pin joint, which allows for forces to be measured separately for each foot. The 4 transducers measure the vertical force applied to the force plate, whereas the central transducer measures sheer force in the forwards-backwards direction parallel to the floor. The force sampling frequency was set at 100 Hz.

Participants, who were wearing comfortable footwear, stood upright with their arms at their sides. Each foot was positioned on one force plate. The medial malleolus of the prosthetic ankle joint on the affected