Base of support feedback in gait rehabilitation

Alexander S. Aruin[1,2,*], Timothy A. Hanke[1] and Asha Sharma[1]

The purpose of this study was to investigate the effect of feedback information about base of support in gait rehabilitation. Sixteen individuals with hemiparesis resulting in narrow base of support, were randomly placed into two equal groups, experimental and control. The experimental group was provided with a portable device that provided extrinsic auditory feedback information about base of support incorporated in the functional context of conventional gait therapy, whereas the control group received a conventional gait therapy only. Changes in step width with treatment were assessed with step print technique. The experimental group of subjects improved their step width with treatment from 0.09 ± 0.003 m to 0.16 ± 0.006 m while individuals assigned to the control group showed smaller improvement from 0.099 ± 0.004 m to 0.13 ± 0.003 m. While both groups demonstrated statistically significant improvement ($p<0.05$), the level of recovery of step width seen in the experimental group was greater. *International Journal of Rehabilitation Research* 26:309–312 © 2003 Lippincott Williams & Wilkins.

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[1]Marianjoy Rehabilitation Hospital, Wheaton, Illinois and [2]Department of Physical Therapy, University of Illinois at Chicago, USA.

Correspondence to: Alexander S. Aruin, Department of Physical Therapy, College of Applied Health Sciences, University of Illinois at Chicago, USA.
Tel: +1 312 355 0904; fax: +1 312 356 4583;
e-mail: aaruin@uic.edu

Introduction

It has been demonstrated in the literature that treatment based on feedback training benefit individuals with central nervous system (CNS) deficits (Basmajian, 1981; Wolf, 1983; Montoya *et al.*, 1993; Peterson *et al.*, 1996; Glanz *et al.*, 1997; Hanke, 1999; Aruin *et al.*, 2000; Walker *et al.*, 2000). By providing special information about the accuracy of studied movement, these individuals may gain better control over their motor system. Specifically, the usefulness of feedback was shown in the gait training of children with various forms of cerebral palsy (Conrad and Bleck, 1980; Flodmark, 1986) and spastic diplegia (Kassover *et al.*, 1986) as well as in improvement of the hand-eye coordination of individuals with cerebral palsy (Talbot *et al.*, 1981). Feedback-based systems may be effective in improvement of stance symmetry of patients with hemiplegia (Shumway-Cook, 1988; Winstein *et al.*, 1989; Wing *et al.*, 1993; Nichols, 1997; Walker *et al.*, 2000) and reduction of the movement time while rising and sitting down (Engardt, 1994a, 1994b).

The importance of walking in activities of daily living makes motor re-education an important part of rehabilitation. The control of the body mass about its center in the frontal plane during walking is a function of lateral foot placement (MacKinnon and Winter, 1993). This foot placement dictates the base of support (BOS) during the stance phases of the gait cycle. Step or stride width, which is reflective of the limits of the BOS in the frontal plane during walking depends on several factors including age, gender, fall status and body dimensions. Impairment of lateral foot placement due to a neurological disease or trauma could significantly reduce BOS. Consequently, reduced BOS during walking may lead to postural instability and increased metabolic cost (Donelan *et al.*, 1999). There are several techniques used in gait therapy directed towards modifying a patient's base of support. The first is based on providing a verbal guidance to the patient when a clinician instructs a patient to move his or her leg out to the side. Another technique, which continues to be used by rehabilitation professionals, is manually providing tactile cues to selected individual muscles or handling the foot of the patient in order to physically assist with placement (Bobath, 1978). Other approaches are based on using mechanical devices that prevent the patient from putting the legs together such as colored markers taped to the floor or a wooden balance beam. These methods however, suffer, respectively, from being too cognitively focused (i.e., specifically trying to have the patient consciously control a single muscle during a complex task or allowing the patient to become a passive recipient of the therapist-induced foot placement), or ecologically obtrusive in the case of walking with a balance beam placed on the floor and between the patient's feet. In contrast to these drawbacks, extrinsic auditory feedback could stimulate more active involvement of the patients in the process of restoring existing or learning new skills. The purpose of the present study was to explore the effectiveness of providing auditory feedback of the BOS offered in addition to conventional gait rehabilitation.

Materials and methods

Sixteen subjects with a narrow base of support due to a recent single unilateral cerebrovascular accident

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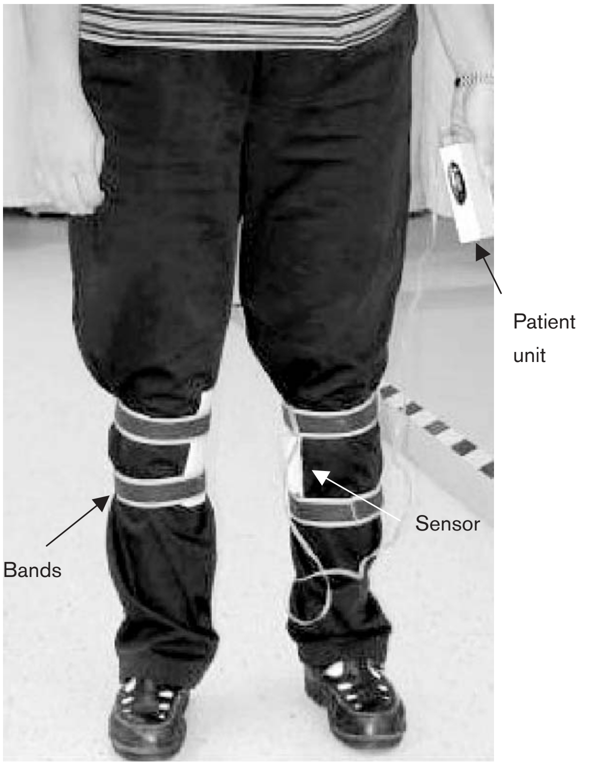
participated in the experiments. Inclusion criteria were the ability to stand and walk up to 4.5–6 m with assistance of a physical therapist and ability to understand and follow verbal instructions. Exclusion criteria were serious or unstable medical conditions, a history of other neurological disease, injury or orthopedic problems, or any other factors that may prevent participation in gait therapy. The study sample included 11 males and five females, mean age 65.34 ± 3.4 years, mean weight 73.5 ± 3.76 kg, mean height 1.72 ± 0.03 m. The mean time from onset of stroke was 18.0 ± 1.8 days with a range of 9–30 days. All the subjects used narrow base quad canes, nine of them had left and the remaining seven had right hemiparesis, seven subjects used an ankle foot orthosis (AFO). The subjects were randomly divided into two equal groups, experimental and control. Both groups of subjects participated in conventional gait therapy sessions (10 days, twice daily for 25 minutes). These sessions consisted of pre gait training focused on weight shifting, stepping, trunk stabilization and facilitation of muscles in the lower extremities, followed by 3–4 ambulations that did not exceed 15–18 m with rest periods of 2–3 minutes in between.

Fig. 1



The extrinsic auditory feedback device used in gait rehabilitation.

The subjects assigned to the experimental group used feedback information on the BOS as an adjunct to conventional gait therapy. They were provided with a device consisting of two sensors that were strapped to the subject's lower extremities below the knees and next to tibial tuberosity with Velcro tape and a main unit that provides distinct signals (tone of 500 Hz) every time the distance between the two sensors is less than a previously established threshold (Aruin, 2001). The design of the device allowed adjustment of its sensitivity depending on the need of a particular patient. While it allows providing feedback when the BOS is too small and too wide, in the current experiments it was used to provide feedback information on a decreased base of support (Figure 1). The accuracy of the device was ± 0.005 m. Subjects assigned to the control group received only conventional gait therapy during which they occasionally received verbal information about their base of support from a physical therapist. The intervention continued for 10 days. All subjects signed the consent form required for participation in the study and completed therapy and testing.

To evaluate base of support and assess the effect of the extrinsic feedback, all the subjects participated in two identical tests during which the magnitudes of step width were recorded. The first test (pre-test) was performed before the intervention started. The second test (post-test) was administered 10 days from the start of therapy. A modified step print technique was used to measure step width (Boenig, 1977). While seated, the surface of each of the subject's shoes was coated with foam pads previously soaked with ink. When the subject walked down the walkway at his or her preferred pace, he or she left 'foot prints' on the floor. In addition, two transparency films were securely positioned on the floor for each foot separately at the end of the walkway. When the subject was standing on the transparencies, contours of each foot were traced with a colored marker as well as the middle point of the heel contour. The position of the heel marker on the heel contour was determined by projecting the vertical line from the middle of the Achilles tendon to a contour of the heel. Thus, each transparency film contained footprints, contours of the foot, and the heel markers. The measurements of step width were performed by applying the transparencies over the dry footprints for the left and right legs accordingly, and the distance between the two heel markers was measured with a ruler. Twelve steps that occurred in the middle of the walking distance were analyzed in each test. The accuracy of measurements of step width using the step print technique was ± 0.001 m. The subjects wore their own shoes that were the same during the entire time of intervention and while participating in both tests.

Statistical analysis included repeated measure ANOVA with group as within subject factor and treatment as

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between group factor. Significance was in all cases set at $p < 0.05$.

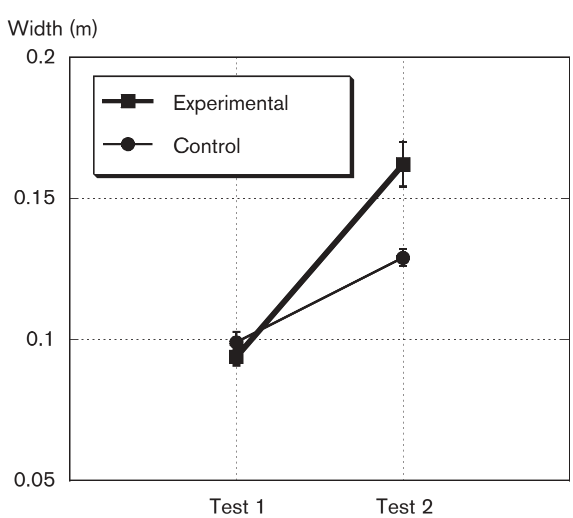
Results

In the experimental group, treated with extrinsic auditory feedback information, the step width measured at the start of training was 0.09 ± 0.003 m and at the time of the second test reached 0.16 ± 0.008 m (Figure 2). This improvement was statistically significant ($F1{,}15 = 100.3$; $p < 0.05$). In the control group, treated with no extrinsic feedback information, the step width was 0.099 ± 0.004 m at the time of first testing and it reached 0.13 ± 0.003 m during the second test. This improvement was also statistically significant ($F1{,}15 = 59.45$, $p < 0.05$). While prior to treatment there was no statistically significant difference in step width between the experimental and control group of subjects ($F1{,}15 = 0.99$; $p = 0.32$) after the end of treatment the difference between the two groups was statistically significant ($F1{,}15 = 135.4$, $p < 0.05$).

Discussion

Positive effect of feedback on the outcome of rehabilitation has been documented in the literature. Winstein *et al.*, (1989) reported that stroke survivors who were provided with visual information about their relative weight distribution through paretic and non-paretic limbs had better standing symmetry than those who received conventional physical therapy (exercises and routine standing balance and weight-shifting training). It was also shown that visual feedback of center-of-pressure position reduced asymmetrical standing more effectively than therapies designed to provide tactile and verbal cues regarding postural symmetry (Shumway-Cook *et al.*, 1988) and that EMG-biofeedback is an effective tool for neuromuscular re-education in the hemiplegic stroke patients (Schleenbaker and Mainous, 1993). A significant beneficial effect of the feedback in increasing the step length of paretic limbs and in correcting step-length asymmetry was reported as well (Montoya *et al.*, 1993). In combination, the above studies have provided clear evidence that abilities specific to the training could be enhanced with a provision of feedback information (Shumway-Cook *et al.*, 1988; Winstein *et al.*, 1989; Sackley and Lincoln, 1990).

Fig. 2



Changes in step width with treatment. Experimental, subjects who were treaded with addition of the extrinsic auditory feedback. Control, subjects who participated in conventional treatment. Standard error bars are shown.

The results of the current experiment showed the utility of the auditory feedback in gait rehabilitation. There was no statistically significant difference in base of support between the two groups of subjects prior to the start of intervention. Both groups demonstrated improvement in the BOS with treatment as practice is believed to be essential for effective learning of complex tasks (Schmidt, 1998; Swanson and Sandford, 1995) and the training activities resembled real-life tasks, presumably maximizing training effects (Carr and Shepherd, 1987; Ma *et al.*, 1999). However, the magnitude of the BOS at the end of intervention was significantly smaller in the control group of patients treated without additional extrinsic feedback. The fact that the experimental group of subjects showed statistically significant results of treatment might be a manifestation of the positive effect of feedback information. However, one may suggest that these could be attributed to differences in interventions: the subjects assigned to the experimental group received an auditory signal (a beep) every time the distance between the feet was small while the subjects participating in the control group received occasional verbal encouragement from a physical therapist. Although those who received such verbal encouragement improved their BOS, they demonstrated smaller improvement of the step width with treatment. There are two possible explanations for this fact. First, the patients may have had difficulties in processing verbal information while attending to their walking pattern. It is possible that patients assigned to the control group were forced to attend differently to the therapists' encouragement as compared to the patients participating in the experimental group. That is, the verbal instruction, which may have been more direct than feedback (*c.f.*, Bartscherer and Lyczak, 1997), may have placed greater demands on the control group than the single auditory cue provided to the experimental group. In light of the fact that added cognitive tasks during gait training could result in gait-related decrements in performance (Haggard *et al.*, 2000), it may be valuable to keep such demands (e.g., instruction regarding multiple components such as muscle activation, pelvic control,

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foot placement) to a minimum. Second, the effectiveness of the new approach may lie in listening to a beep during gait training that was quite a new phenomenon for most of the patients. Thus the effect of novelty should not be disregarded. In this connection, the experimental group of subjects may have been able to more easily concentrate on a relatively simple cue than might be expected when listening to the speech stimuli (a phrase or a word from the therapist). Moreover, it may be that information associated with the extrinsic auditory cue was tied more closely to the goal of foot placement and proper base of support and therefore overall walking stability. This is one potentially unique aspect of this form of feedback and addressing information towards the appropriate level of movement control may have contributed to the small but significant benefit.

The feedback device used in the current study was set up to provide information on a narrow BOS that is also observed in individuals with Parkinson's disease, cerebral palsy, and in the elderly. It is expected that using the device that is set up to detect BOS that is too wide would benefit other individuals with impairment of lateral foot placement such as persons with cerebellar ataxia. The fact that this impairment could be resolved sooner with the use of extrinsic auditory feedback may afford the rehabilitation professional more time to direct treatment at other aspects of walking function. For example, the ability to adapt one's gait to different environmental contexts could be practiced once a minimum of stability through improved foot placement was achieved. Finally, we acknowledge that this was a small sample of acute post-stroke subjects. The results of this study encourage us to consider expanding future trials to those chronic post-stroke subjects who show altered or greater variability in foot placement particularly as it relates to the functional BOS during walking. Since this may also improve overall gait stability it may be prudent to extend the analysis to incorporate measures of balance during gait.

In conclusion, the extrinsic auditory feedback technique, which was incorporated in a functional context of gait therapy, showed a positive effect in improving base of support while walking.

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