ORIGINAL ARTICLE

Effects of Ankle Proprioceptive Interference on Locomotion After Stroke

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ABSTRACT. Lin S-I, Hsu L-J, Wang H-C. Effects of ankle proprioceptive interference on locomotion after stroke. Arch Phys Med Rehabil 2012;93:1027-33.

Objective: To examine the effects of vibration-induced ankle proprioceptive interference on the locomotion of patients with stroke with intact and impaired ankle joint position sense (JPS).

Design: Cross-sectional.

Setting: Rehabilitation department in a tertiary hospital.

Participants: Ambulatory patients (N=35) with unilateral stroke received an ankle joint repositioning test and were classified into intact (n=16) or impaired (n=19) JPS group.

Interventions: None.

Main Outcome Measures: The plantar sensitivity and leg muscle strength were tested. Patients were instructed to walk at a self-selected pace on a computerized pressure sensor walkway under 3 conditions: no, affected, or unaffected Achilles' tendon vibration. The stride characteristics of the affected limb were analyzed.

Results: Patients with intact and impaired JPS did not differ in their plantar sensitivity or leg muscle strength. The differences in the stride characteristics were nonsignificant between vibration and nonvibration conditions. Shorter single support and longer swing phase were found with the affected side vibration compared with the unaffected side vibration. Patients with intact and impaired JPS did not respond to the proprioceptive interference differently.

Conclusions: After stroke, there could be changes in the central sensory regulation for locomotion control and vibration-induced afferent inputs from the ankle might be viewed as sensory disturbances. Further studies that manipulate other sensory inputs are needed to gain a better understanding of the central sensory integration for locomotion control after stroke.

Key Words: Ankle; Locomotion; Proprioception; Rehabilitation; Sensorimotor feedback; Stroke.

GAIT IMPAIRMENTS are common after stroke and believed to be related to the residual sensory and motor deficits of the patients.[1,2] There has been a large body of evidence linking motor deficits to gait impairments in patients with stroke.[3-6] However, how sensory deficits would affect locomotion control is poorly understood.[7]

Sensory inputs from the somatosensory, visual, and vestibular systems can contribute to the control of locomotion.[8] Although stroke may affect all the 3 types of sensory functions, the incidence of somatosensory impairments is particularly high, ranging from 11% to 85%, depending on how sensory function was tested.[7,9,10] Research findings pertaining to the impact of somatosensory impairments in locomotion control in patients with stroke are inclusive. Poorer ankle joint position sense (JPS) has been found to be related to greater gait deviations in patients with stroke.[11-13] Using the Fugl-Meyer Assessment Sensory score, a summation score of light touch and position sense, 1 study reported significant correlations[14] while others found nonsignificant and low correlations between the residual somatosensory function and stride characteristics.[1,2,5,15]

The inconsistency in research findings may partly be explained by changes in central sensory weighing after stroke. The disruption of visual inputs has been found to lead to a greater increase in postural sway than does the disruption of somatosensory inputs from the lower limbs in patients with stroke.[16-18] This finding suggests that after stroke, postural control may have a greater reliance on visual than leg somatosensory inputs. Such a shift in central sensory weighing may reduce the impact of sensory loss and alter the relationship between somatosensory deficits and gait deviations.

For locomotion control, various research paradigms have been developed to determine the roles of the different sensory systems in healthy adults. Specifically, the role of proprioceptive input, a subtype of somatosensory input, can be investigated by using mechanical vibration. Mechanical vibration to muscle or tendon can selectively activate the Ia afferent, a primary proprioceptive receptor, and elicit sensory inputs indicating, though falsely, lengthening of the vibrated muscle.[19-21] When mechanical vibration was applied to the lower limb muscles of healthy adults whose visual inputs were removed or diminished during walking, it elicited changes in walking velocity, muscle activation patterns, or joint kinematics.[22-24] Such vibration-induced changes were absent when the subjects walked with their eyes open.[22,25] These findings suggest that for healthy adults different modalities of sensory inputs are weighed and integrated for locomotion control and that when the rest of the sensory inputs are present and correct, conflicting (or false) ankle proprioceptive inputs can be resolved.

Stroke is often associated with impaired supraspinal control of sensorimotor function and possibly the ability for reweighing different sensory inputs for movement control. It is thus

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List of Abbreviations

JPS	joint position sense
MANCOVA	multivariate analysis of covariance

possible for patients with stroke that proprioceptive interference during walking could not be successfully resolved and the gait patterns would be affected. Furthermore, because residual sensory inputs are critical for resolving conflicting sensory conditions, patients with stroke with greater sensory impairments would be affected to a greater extent. During activities of daily living, conflicting sensory inputs may be experienced during walking, such as when walking on compliance surfaces. It is unclear how patients with stroke would respond to these proprioceptive inferences. The purpose of this study was to determine the effects of proprioceptive interference from the ankle joint on the locomotion pattern of patients with stroke. It was hypothesized that ankle proprioceptive interference would significantly affect the locomotion pattern and that study participants with impaired ankle JPS would be affected to a greater extent. The findings of this study will help to gain a better understanding of sensory integration for locomotion control in patients with stroke and provide information for the development of effective sensorimotor training to improve the gait in the patients.

METHODS

Study Participants

A convenience sample of study participants was recruited from the department of rehabilitation of a tertiary hospital. Patients who had been diagnosed to have unilateral stroke and were (1) able to walk independently for at least 10m with or without devices, (2) without other known neurologic, orthopedic, or cardiopulmonary problems that might limit walking, and (3) able to follow verbal commands were recruited. The study was approved by the human subject review board of the institution where the study was conducted. All study participants provided written consents.

Forty-two patients were recruited. Among them, 3 study participants failed to complete the experiments because of hypersensitivity of the plantar sole (n=1) and tiredness during gait assessment (n=2). Another 4 patients were excluded because their gait was indiscernible by the pressure sensor walkway because of foot dragging. As a result, the data from 35 study participants were analyzed.

General Procedures

The study participants first underwent the Mini-Mental State Examination and a series of sensorimotor assessments including plantar cutaneous sensation, ankle JPS, muscle strength of the lower extremities, and the Fugl-Meyer lower extremity motor assessment. After these assessments, the study participants were asked to walk on a pressure sensor walkway at self-selected speeds with or without Achilles' tendons vibration. A custom-made vibration system that consisted of a digital function generator, a signal amplifier, and 2 vibrators was used. The vibrator itself consisted of a biaxial direct current motor equipped with eccentric masses. Each motor was embedded into an 8.5-cm long plastic cylinder (diameter 3.5cm, weight 400g). It has been reported that vibration at frequencies of 10 to 160Hz and amplitudes of 0.2 to 2mm could elicit illusory sensation of joint motion,[19,26] as well as changes in blood flow in the sensory cortex.[27] Furthermore, tendon vibration to the tibialis anterior in standing subjects could induce compensatory postural sway related to the vibration-induced illusory sensation of changes in the ankle joint angle.[28] Thus, this study chose to use vibration with 80Hz in frequency and 1mm in amplitude.

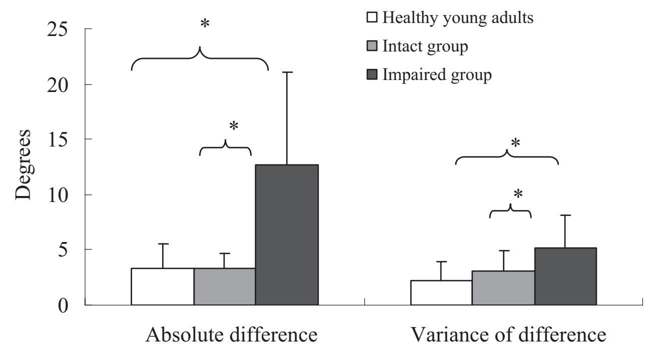

Fig 1. The means of absolute difference and variance of difference of healthy young adults and patients classified into intact and impaired groups. The impaired group differed significantly from the healthy young and intact groups. *$P<.05$.

JPS Test

The JPS was evaluated by a joint reposition test with a set of electrogoniometers[a] attached to the long axis of the tibia and the fifth metatarsal bone. The study participants were seated with the thigh completely supported by the seat of the chair and the lower leg and foot dangled and remained motionless and relaxed. The examiner first moved the affected foot up or down 10° without any heel motion, held the position, and then asked the study participant to actively move the unaffected foot to match the corresponding ankle joint angle. The test was repeated thrice, and the differences between the 2 corresponding joint angles in the joint reposition test were recorded. Test-retest reliability of the measurement was conducted in 20 healthy young adults and found that the intraclass correlation coefficient was .451 ($P=.05$).

For the classification of the JPS, a set of criteria determined a priori on the basis of unpublished data from this laboratory using the same experimental procedures on healthy young adults was used. Two parameters, mean difference of joint reposition error and variance of difference of joint reposition error, were used to represent the performance of the joint reposition test. The mean difference of joint reposition error was the mean of the absolute differences between the 2 corresponding joint angles in the joint reposition test of the 3 repetitions, representing the accuracy of the JPS. The variance of difference of joint reposition error was the pairwise difference of the absolute differences between the 2 corresponding joint angles in the joint reposition test of the 3 repeated trials, representing the variability of the JPS. When 2 of the 3 mean differences of joint reposition error, or both the minimal and maximal mean differences of joint reposition error, were beyond 95% of the normative data, impaired ankle JPS would be assigned. Figure 1 shows the means of mean difference of joint reposition error and variance of difference of joint reposition error of young adults (from the pilot study) and the study participants classified into intact and impaired groups. It can be seen that while the intact group had JPS similar to that of healthy young adults, the impaired group had significantly greater reposition error and hence poorer JPS.

Because the status of the knee JPS could also affect the outcome of this study, the JPS of the knee joint was also assessed. The electrogoniometers were attached to the long axis of the femur and the tibia. From the same initial position as in the ankle joint reposition test, the examiner moved the affected lower leg upward from vertical for 30° to 45°, held the position, and asked the subject to actively