

# Effects of foot pressure using the elastic band with rings during sit-to-stand in persons with stroke



Young-In Hwang, Ki-Song Kim

Department of Physical Therapy, College of Life and Health Science, Hoseo University, Asan, Republic of Korea

**Objective:** Persons with stroke have a tendency to exhibit asymmetric weight-bearing during sit-to-stand because due to the attempt to support themselves with the non-paretic foot. However, there are few devices that can assist with sit-to-stand (STS) performance. This study was designed to investigate the use of the elastic band with rings (EBR) in improving weight-bearing effectively in persons with stroke during STS training.

**Design:** Cross-sectional study.

**Methods:** Thirteen stroke survivors participated in the study. An EBR was applied onto the patient during STS activity. The foot pressure was measured before and after wearing the EBR, with a 5-minute rest period between measurements. Subjects were asked to perform each test twice with and without the EBR. Bilateral foot pressures were measured with standing posture being divided into the forward and backward aspects. The foot contact pressure during STS activity was measured with the CONFORMat System.

**Results:** With EBR, the forward pressure of the affected foot significantly increased while the less-affected forward foot pressure significantly decreased ( $p=0.015$  and  $p=0.023$ , respectively). The backward foot pressure did not differ significantly in the two limbs, and there was no difference with and without the EBR in terms of the total pressure of the affected foot. There was a significant difference with and without the EBR in the total pressure of the less-affected foot ( $p<0.05$ ).

**Conclusions:** STS training with the EBR has been shown to improve weight-bearing of both feet while decreasing the total pressure of the less-affected foot in stroke survivors. Therefore, we suggest that the EBR is a useful tool for STS training for persons with stroke in the clinic.

**Key Words:** Self-help devices, Stroke, Rehabilitation

## Introduction

For functional independence, individuals with stroke need to achieve sit-to-stand (STS) ability before performing other activities [1]. There is also a tendency toward asymmetric weight-bearing during STS because patients usually support themselves with the non-paretic foot [2]. Engardt and Olsson [3] reported that, following stroke, patients performed more asymmetric weight-bearing with the less-affected leg. It is important to maintain the base of support to prevent falling at the end of STS [4]. Hesse *et al.* [5] reported that, during STS, the center of gravity was tilted laterally by

approximately 78% before the seat-off and by over 50% after the seat-off phase in individuals with stroke compared with healthy individuals. The postural asymmetry can cause secondary gait disability after a stroke event [6,7].

STS training is usually introduced early in a rehabilitation program [8-10]. STS is comprised of four phases: 1) the flexion-momentum phase, which comprises the movement initiated before lifting off the buttocks; 2) the momentum-transfer phase, in which the center of mass (COM) of the body is transferred anteriorly and upward, occurring simultaneously with maximal ankle dorsiflexion; 3) the extension phase, when hip extension occurs; and 4) the stabilization

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Corresponding author: Ki-song Kim

Department of Physical Therapy, College of Life and Health Science, Hoseo University, 20 Hoseo-ro 79beon-gil, Baebang-eup, Asan 31499, Republic of Korea  
Tel: 82-41-540-9971 Fax: 82-41-540-9975 E-mail: [kskim68@hoseo.edu](mailto:kskim68@hoseo.edu)

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phase, which starts at 0° of hip extension and continues until the motion is stable [8].

Following a stroke, patients rise from a chair by bearing more weight on the non-paretic foot from phases 1 to 4, although they improve and perform symmetric STS through visual feedback [3], imagery group training [11], and by altering the foot positions [9]. Bohannon *et al.* [12] reported that there is at least a 50% error difference between the perceived body weight born on the foot and the practical distribution in healthy people. Individuals with stroke have a reduced perceived error compared with the practical weight at 50% of body weight [13]. Cheng *et al.* [14] reported that, following stroke, patients who had undergone biofeedback training showed improved STS and decreased the risk of falling by distributing their weight symmetrically. Symmetrical movement not only increases weight-bearing by the affected leg but also prevents the learned non-use syndrome and aids in the recovery of functional movement [14,15].

Although research on the use of smart mobile walkers [16] and exoskeletal robots to provide support for STS are currently being actively conducted [17], they are not well acknowledged due to high cost. The elastic band with rings (EBR) is designed to provide strength to the muscles through the axial tension created by the elastic and the ring of the EBR. Therefore, this study aimed to investigate the effects of use of EBR during STS on weight-bearing in persons with stroke.

## Methods

Thirteen stroke survivors were voluntarily involved in the study. All of participants were in-patients at Seoho Hospital in Busan, Republic of Korea. There were 10 males and 3 females; five had right hemiplegia and eight had left hemiplegia. The inclusion criteria were (a) a diagnosis of hemiplegia due to hemorrhagic or ischemic stroke, (b) more than 6 months post-stroke, (c) the ability to follow simple instructions, (d) the ability to walk independently or with an assistive device, and (e) no orthopedic problems involving the lower extremities that would affect gait [18]. The exclusion criteria were (a) a stroke involving more than one hemisphere, (b) more than two strokes, and (c) pre-morbid or other orthopedic problems that would impede gait patterns [18]. All of them provided their informed consent prior to the execution of the study. Patients demographic information are summarized in Table 1. Hwang *et al.* [19] designed the EBR, which consists of a 515-cm-long green

**Table 1.** Characteristics of participants (N=13)

Characteristic	Value
Sex	
Male	10 (76.9)
Female	3 (23.1)
Affected side	
Left	8 (61.5)
Right	5 (38.5)
Diagnosis	
MCA infarction	2 (15.4)
Cerebral infarction	3 (23.1)
ICH	6 (46.2)
ICH and SAH	1 (7.7)
Basal ganglia infarction	1 (7.7)
Age (yr)	58.00 (7.72)
Height (cm)	165.47 (7.23)
Weight (kg)	62.70 (9.59)
Post onset (mo)	32.00 (14.55)

Values are presented as n (%) or mean (SD).

The sum of the percentages does not equal 100% because of rounding.

MCA: middle cerebral artery, ICH: intracerebral hemorrhage, SAH: subarachnoid hemorrhage.

elastic band and 4 plastic rings made of thin, flexible polyethylene. We used one wrap of the green elastic band with the four plastic rings placed on the anterior tibia, posterior aspect of the knee joint, middle of the thigh, and posterolateral hip joint [19-21]. For consistency, one experienced therapist applied comfortable tension [19,20]. Also, in order to find the most comfortable tension level for each patient, the device was applied onto the patient at least 3 times and the tension that was reported to be the most comfortable by the patient was used.

The foot contact pressure during STS activity was measured with the CONFORMat System (Model #5330; Tekscan, Boston, MA, USA), a portable interface pressure operating system that can capture the foot pressure distribution and contact area. Before starting, the operating system was checked by loading and unloading it several times. The sensor was equilibrated and calibrated using the instrumentation supplied by the manufacturer. The CONFORMat System was placed on the floor for foot contact after the sensor was prepared. It recorded the foot contact pressure distribution and calculated the mean value from the readings. Measurements were made at a frequency of 10 Hz for 10 seconds using I-Scan ver. 6.20 (Tekscan).

The subjects started in a sitting position with their feet shoulder-width apart. Both feet were parallel so that the lines



**Figure 1.** Application of the elastic band with rings on a patient during sit-to-stand activity. (A) Anterior view. (B) Lateral view. (C) Sit-to-stand view.

from the centers of the knee joints to the lateral malleoli were vertical to the CONFORMat [22] (i.e., the knee and ankle joints were both at approximately 90°). The seat height for each subject was 100% of the lower leg length, and the thigh support was at 50% of the thigh length. The lower leg length was measured from the center of the knee joint to the floor, and the thigh length was the distance between the greater trochanter and lateral knee line [22,23]. Initially, the trunk was upright. The bare feet were on the CONFORMat System. When the investigator said “start,” the subjects rose from the sitting position. The pressure applied to the soles of the feet was assessed at the start of the sitting state, and was stopped when the hip and knee were extruded to the completed standing posture (Figure 1). An assistant was positioned near the subject to prevent him/her from falling. The foot pressure was measured before and after wearing the EBR, with a 5-minute rest period between measurements. Before testing, an investigator demonstrated the STS activity, and the subjects were allowed to practice it once or twice on the mat. They were also allowed to practice after the EBR was put on and the elastic tension was checked. The mean foot pressure of both feet was compared using the paired t-test. The differences in foot pressure between the values obtained during STS activity with and without the EBR were analyzed using IBM SPSS Statistics ver. 20.0 (IBM Co., Armonk, NY, USA). The level of significance was set at  $p < 0.05$ .

## Results

With EBR, the forward pressure of the affected foot sig-

**Table 2.** Peak foot pressure in stroke patients on sit-to-stand activity (N=13)

Foot pressure (N/cm <sup>2</sup> )	Without EBR	With EBR	<i>p</i> -value
Affected forward foot	4.06 (1.19)	4.86 (1.17)	0.015*
Less-affected forward foot	5.01 (1.27)	4.40 (1.42)	0.023*
Affected backward foot	4.63 (1.82)	4.56 (2.05)	0.851
Less-affected backward foot	7.52 (2.49)	7.21 (2.08)	0.511
Total affected foot	8.69 (2.30)	9.43 (1.68)	0.148
Total less-affected foot	12.53 (2.97)	11.61 (2.42)	0.028*

Values are presented as mean (SD).

EBR: elastic band with rings.

\* $p < 0.05$ .

nificantly increased while the less-affected forward foot pressure significantly decreased ( $p=0.015$  and  $p=0.023$ , respectively). The backward foot pressure did not differ significantly in the two limbs, and there was no difference with and without the EBR in terms of the total pressure of the affected foot. There was a significant difference with and without the EBR in the total pressure of the less-affected foot ( $p=0.028$ ; Table 2).

## Discussion

This study measured the pressures of the affected and less-affected foot with and without the EBR during STS activity. With the EBR, the forward foot pressures of both feet were increased significantly, while the total pressure of the less-affected foot was decreased significantly.

One of the reasons for this is that the ‘sense of effort’ [24,25] is enhanced with the tension of the elastic band on the affected foot. The ‘sense of effort’ was defined as the sensory experience that leads the muscle to control the production of power [25]. The sense of effort is produced through both feed-forward and feedback mechanisms. With the EBR, the tension or force from the feedback neural signals (i.e., the ascending sensory information) [24,26] is used to increase the stability of the ankle, knee, and hip joints to increase weight-bearing on the affected side and decrease the weight-bearing on the less-affected side.

Additionally, the forward pressure of the affected foot was increased selectively compared with the backward pressure. Characteristically, stroke survivors tend to invert the affected foot [27,28]. The EBR supports the transverse and longitudinal arches to produce better foot position [19], which provides sufficient resistance to the floor and proprioception on the affected foot in individuals with stroke.

Moreover, it might provide sensory input to the affected forward foot to supplement sensory deficits, consequently decreasing the forward pressure of the less-affected foot. According to Brière *et al.* [2], it is better to perceive the affected side than to increase the knee effort. When patients first attempt to stand from a sitting position following a stroke, they tend to load their weight on the less-affected side due to non-use syndrome [29,30]. With the EBR, perception of the affected side might reduce the learned non-use syndrome.

To achieve STS, the COM of the body must be moved forward during the preparatory phase and reach a maximum velocity before the seat-off phase [31]. This maximally increases the vertical force of the foot, while the trunk moves forward to reach the seat-off phase [31,32]. As the vertical force increases, the COM should move forward to achieve STS. We postulated that the forward pressure of both feet would increase. With the EBR, however, the pressure of the less-forward foot decreased significantly. This is as important as increasing the pressure of the affected forward foot because the pressure of the less-affected foot could not decrease without sufficient perception of the affected foot. Taub *et al.* [30] and Bohannon and Larkin [33] also reported that individuals with stroke achieved symmetrical movement by increasing of their attention and effort. By wearing the EBR, stroke survivors increased their attention to the affected foot and increased the muscle effort via the tension of the elastic band.

In this study, the subjects started with the knee directly above the ankle. This increases the duration, the distance of the COM, and the gastrocnemius and soleus activity compared with having the backward foot about 10 cm behind this vertical line during STS [22]. It is relatively difficult compared with having one foot backward, but the position could be selected based on function. The foot directly under the knee causes mono-articular muscles, such as the vastus medialis, tibialis anterior and soleus, to lift the body mass to a greater distance [22].

The patients were instructed to assume a symmetrical foot position during STS, although symmetric and asymmetric training have different clinical advantages. Some authors suggest that symmetric practice not only increases weight-bearing on the affected side but also prevents learned non-use syndrome and assists in the recovery of functional movement [14,15]. In comparison, asymmetric STS training with the affected foot behind the less-affected foot increases weight-bearing on the affected side [9,34,35] and results in

greater activity of the tibialis anterior and quadriceps. Farqalit and Shah Nawaz [36] also reported that an asymmetrical foot position improved balance and upright mobility in those affected by stroke. Therefore, future investigations need to examine the effects of symmetric and asymmetric foot positions in STS training with the EBR on the foot pressure and muscle activity in persons with stroke.

## Conflict of Interest

The authors declared no potential conflicts of interest with respect to the authorship and/or publication of this article.

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