

Original Article

Immediate effects of an elastic arm sling on walking patterns of chronic stroke patients

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Abstract. [Purpose] We developed a new arm sling with an elastic bandage which we hereafter refer to as “the elastic arm sling”. This study investigated the immediate effects of the elastic arm sling on the gait patterns of stroke patients. [Subjects and Methods] Thirteen stroke patients were enrolled in this study after providing their informed consent. They walked on a GAITRite mat twice, with a 5-min rest between the trials. [Results] Significant improvements were seen in cadence and walking velocity during walking while wearing the elastic arm sling. Furthermore, patients who used the elastic arm sling showed significant increases in step lengths of the affected and unaffected limbs. The stride lengths of the affected and unaffected sides while wearing the elastic arm sling and those without the elastic arm sling also significantly differed. [Conclusion] These results demonstrate that the elastic arm sling is a useful tool for the gait training of stroke patients, especially cadence, walking velocity, and the step and stride lengths of both limbs. Therefore, therapists should use the elastic arm sling as a gait-training assistive device for stroke patients.

Key words: Elastic arm sling, Hemiplegic gait, Orthotic devices

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INTRODUCTION

There are many ways of improving the gait for hemiplegic patients, including ankle-foot orthoses (AFOs)^{1, 2)}, functional electric stimulation (FES)³⁾, electromyography (EMG) biofeedback⁴⁾, and robotic devices⁵⁾. However, few studies of hemiplegic gait have examined the use of assistive devices such as an arm sling. A single-strap hemi-sling was used in several studies which investigated the gait patterns⁶⁾, balance⁷⁾, and energy consumption⁸⁾ of stroke patients. Nevertheless, wearing a hemi-sling for long periods can cause inappropriate movement patterns in the upper trunk. Also, Faghri et al.⁹⁾ suggested that a hemi-sling impedes functional activities and intensifies flexor synergy in the upper trunk.

There is a need for a new assistive device for improving the alignment of the upper body while simultaneously improves gait pattern by increasing stability on the affected side. Additionally, such a device could be used to help reshape the elbow and wrist on the affected side, and to support the weight of the affected arm itself. Thus, we designed a new arm sling with an elastic bandage, which we hereafter refer to as “the elastic arm sling”, and investigated the ef-

fects of wearing the elastic arm sling on the gait patterns of chronic stroke patients.

SUBJECTS AND METHODS

This study investigated how the gait patterns of stroke patients were changed by wearing the elastic arm sling. The participants were 13 patients (9 males, 4 females) who had been diagnosed as having had a cerebrovascular accident. All subjects enrolled voluntarily after providing their informed consent. The study was explained to the subjects, and their written informed consent was obtained before the study was initiated. The selection criteria were diagnosis of stroke due to intracranial haemorrhage (ICH) or infarction, more than 6 months post stroke, Functional Ambulatory Category (FAC) score > 3, and ability to follow simple instructions. Subjects were excluded if they had medical problems other than a neurological lesion that affected their gait patterns, or bilaterally affected limbs. The general characteristics of the subjects are shown in Table 1. Ethical approval was obtained from the Inje University Faculty of Health Science Human Ethics Committee, and all subjects signed an informed consent form prior to their participation.

Data was collected using a GAITRite system (CIR Systems, Easton, PA, USA), which can analyze temporal and spatial parameters of gait. The elastic arm sling consisted of four plastic rings made of thin, flexible polyethylene and three pieces of a green elastic bandage produced by Thera-Band[®] (Akron, Ohio, USA), which were lapped over each shoulder and the affected arm. Patil and Rao¹⁰⁾ suggested

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Table 1. Characteristics of the hemiplegic subjects

Subjects	Gender	Age (years)	Paretic side	Dx.	Height (cm)	Weight (kg)	Since onset (months)
1	M	65	Lt.	Infarction	167.1	63.4	53
2	M	64	Lt.	ICH	173.5	60.8	24
3	M	59	Rt.	ICH	169.2	63.3	22
4	M	52	Rt.	ICH	175.8	78.0	60
5	M	49	Rt.	ICH	175.0	78.3	60
6	M	81	Rt.	Infarction	170.9	62.8	36
7	M	66	Rt.	Infarction	165.4	49.1	38
8	M	48	Rt.	CVA	155.3	57.4	36
9	M	78	Rt.	Infarction	159.6	64.7	41
10	F	74	Rt.	Infarction	141.5	52.0	120
11	F	48	Rt.	SAH	150.0	55.9	24
12	F	55	Lt.	ICH	158.2	56.3	34
13	F	64	Lt.	Infarction	162.7	59.7	40

Dx, diagnosis; F, female; ICH, intracranial cerebral hemorrhage; Lt, left; M, male; Rt, right; SAH, subarachnoid hemorrhage

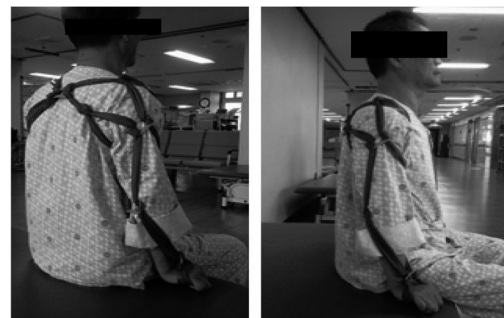
that the green Thera-Band® elastic bandage provides a moderate amount of resistance. The crossover of the figure-of-eight elastic bandage with a ring should be centred over the spine and between the scapulae. The wrist should be at about 30° extension, the elbow should be at 20–30° of flexion or less, the elbow strap should be approximately 2 cm distal to the olecranon process, and the shoulder should be in external rotation (Fig. 1). Each elastic arm sling was applied by a single, trained therapist. The tension was adjusted until it was comfortable for the patient. When the participants performed the walking test in bare feet on the GAITRite mat, their walking performance was displayed. The patients were asked to walk at a comfortable speed and were provided with assistance when required. Each trial was performed twice by each patient, with a 5-min rest between tests. We analyzed the immediate effects of walking while wearing the elastic arm sling using the paired t-test. We used SPSS software (ver. 19.0 for Windows, SPSS, Chicago, IL, USA). Statistical significance was accepted for values of $p < 0.05$.

RESULTS

The effect of wearing the elastic arm sling on cadence was marginal ($p = 0.05$), however, wearing the sling was associated with a significant improvement in velocity ($p = 0.008$). Furthermore, patients who used the elastic arm sling showed increases in the step lengths of the affected ($p = 0.016$) and unaffected ($p = 0.027$) limbs. There were also significant differences in the stride lengths of the affected ($p = 0.005$) and unaffected ($p = 0.018$) sides between with and without the use of the elastic arm sling (Table 2).

DISCUSSION

We developed the elastic arm sling which consists of three pieces of elastic bandage and four plastic rings. It might provide scapular and shoulder stability and improve

**Fig. 1.** The elastic arm sling**Table 2.** Differences of gait parameters with and without the elastic arm sling in stroke patients

Gait parameters	Without EAS	With EAS
Cadence (steps/min)	58.4 ± 23.9	64.4 ± 27.0
Velocity (cm/sec)	25.2 ± 19.7	30.1 ± 21.0**
Affected step length (cm)	25.4 ± 12.1	27.5 ± 11.6*
Unaffected step length (cm)	23.5 ± 12.0	25.7 ± 11.2*
Affected stride length (cm)	49.3 ± 22.7	54.0 ± 22.0**
Unaffected stride length (cm)	49.3 ± 23.0	53.5 ± 21.8*

Values are means ± SD; *, $p < 0.05$; **, $p < 0.01$
EAS, elastic arm sling

alignment of the arm through the tension of the elastic bandage. Also, the four plastic rings might contribute to the improvement of the arm position of the affected arm. This might provide shoulder stability without restricting arm motion, and increase body awareness through the establishment of elastic tension in the scapulae, shoulder, elbow, and wrist joints. We hypothesised that the elastic arm sling might help to improve the gait patterns and dynamic stability of stroke patients during walking.

This study found no definitive evidence of a change in cadence ($p = 0.05$) during walking while wearing the elastic arm sling, but mean cadence values with and without the elastic arm sling were quite different. Walking velocity significantly increased in patients who were wearing the elastic sling ($p = 0.008$). In stroke patients, impaired arm swing could be one of the factors that limit the walking speed¹¹. Some authors have asserted that the unaffected arm could compensate through greater swing when the affected arm moves passively while walking¹². Other researchers have reported that walking velocity increases during the transition from passive to active arm swing suggesting that walking speed is related to the recruitment of arm movement¹³. Thus, we inferred that gait velocity would be related to the improvement of the recruitment of arm movement with the elastic arm sling.

We inferred that the elastic arm sling might facilitate some muscles that support the scapulae and upper trunk, which would also simultaneously facilitate the oblique muscles, which are related to lower trunk stability¹⁴. In addition, some authors have indicated that an arm sling assists the affected side, by establishing a proper alignment of the glenohumeral joint of the paretic arm¹⁵. However, these propositions need to be verified by further research. For the present study, we hypothesized that the elastic arm sling might enhance stability through a feedback mechanism, providing support for the paretic side and encouraging better positioning of the paretic arm. The step and stride lengths of the affected and unaffected sides both significantly increased during walking with the elastic arm sling. Spasticity in stroke patients leads to adduction of the shoulder, and flexion of the elbow, wrist, and fingers⁶, implying that paretic arm swing might not be proper. In hemiplegic patients, paretic arm swing amplitude usually reduces and arm swing of the unaffected side gets larger¹⁶, which means increased asymmetry of arm swing. In other words, the elastic arm sling might decrease asymmetric arm swing, resulting in decreased lateral leaning, leading to improved gait stability and step and stride lengths increases. Maki¹⁷ reported that changes in gait, such as in walking velocity and stride length, were related to individuals' fear of falling. Thus, stride-to-stride variability may predict falling and may be a useful measurement of an individual's fall risk¹⁷. We suggest that the elastic arm sling should be adopted in gait training instead of a hemi-sling because it increases step and stride lengths on both sides, which may decrease the fear of falling of stroke patients.

There were some limitations to this study. Our sample size was too small to allow generalization to all stroke patients. The elastic arm sling was only worn by patients during walking for a short period. The assumption that some muscles in the upper extremity were facilitated by the arm

sling needs verifying because we didn't measure muscle activities while walking with the elastic arm sling. We focused on the gait patterns of stroke patients wearing the elastic arm sling because we wanted to establish its effect on gait patterns in order to recommend its clinical use. In future studies, the gait patterns and EMG activities of the elastic arm sling should be researched and compared with those of several kinds of arm slings used by patients with stroke.

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