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PREVENTION & REHABILITATION: Randomised Study

Immediate effects of ankle eversion taping on gait ability of chronic stroke patients

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ABSTRACT

Objectives: The purpose of this study is to assess the immediate effects of applying ankle eversion taping using kinesiology tape in patients with foot drop after stroke.
Design: Randomized cross-over trial.
Method: In this study, fifteen subjects with stroke underwent three interventions in a random order. Subjects were randomly initially assigned to an ankle balance taping, placebo taping, and no taping each group. The ankle eversion taping was used for mechanical correction. Ankle eversion taping is involved in ankle dorsiflexion and eversion. The placebo taping began from both malleolus and was applied up to the middle point of the lower limb. Gait ability was assessed by the GAITRite System. The measured gait variables are gait velocity, step length, stride length, H-H base support, and cadence. All of the measurements were performed immediately after intervention.
Results: Our results showed gait function in chronic stroke patients was improved after ankle eversion taping. Velocity, step length, stride length and cadence under the ankle eversion taping conditions significantly increased ($p < 0.05$) compared to the placebo and no taping conditions. Ankle eversion taping significantly reduced ($p < 0.05$) H-H base support compared to the no taping condition.
Conclusions: We conclude that the application of ankle eversion taping that uses kinesiology tape instantly increased the gait ability of chronic stroke patients with foot drop. However, more research is necessary to identify the long-term effects of the ankle eversion taping.

1. Introduction

Stroke patients suffer sensorimotor impairment including abnormal gait, lack of proprioception, spasticity, disorder in the selective motor control, and muscle weakness (Balaban and Tok, 2014). In many stroke patients, the abnormal hemiparetic gait demands much energy and limits mobility (Chen et al., 2005). Hemiparetic gait can be caused by muscle weakness, weight bearing and balance problems, spasticity, exaggerated deep tendon reflex, and co-contraction of synergic pattern muscles (Byun et al., 2011). Foot drop due to the stiffness of plantar flexors, weakness of dorsiflexors, and increased spasticity is a primary cause (Yocheved et al., 2009). The gait pattern in a patient with foot drop shows slower cadence, shorter stance phase on the affected side, shorter step and stride length (Titianova et al., 2003). In severe cases, it can increase the risk of falls (Machintosh et al., 2006). Therefore, improving gait speed and gait pattern with continuous foot drop treatment is widely perceived as the most important goal in stroke rehabilitation (An-Lun et al., 2003).

Ankle Foot Orthosis (AFO) is the commonest treatment to improve foot drop and increase gait in patients with stroke. AFO can provide stability of the paretic limb during stance phase and supports dorsiflexion of the ankle of paretic limb during swing phase by maintaining a neutral ankle position (Patricia et al., 2013; Fatone et al., 2009). Ferreira et al. improved gait velocity and cadence by applying AFO in patients with stroke, proving the effectiveness of AFO (Tyson et al., 2013). Tyson et al. reported that AFO could increase energy cost of walking, ankle and knee kinematics, and kinetics in stroke patients (Folstein et al., 2013).

Functional Electrical Stimulation (FES) is frequently used to improve gait function in stroke patients. FES activates the

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dorsiflexor by stimulating the common peroneal nerve during the swing phase (Dirk et al., 2013). Shendkar et al. reported that quality of walking and foot clearance was improved for three months after FES intervention in stroke patients with foot drop (Shendkar et al., 2015). Taylor et al. argued that FES is a practical, long-term, cost-effective method to correct foot drop (Taylor et al., 2013).

However, FES and AFO are expensive, uncomfortable to carry, and aesthetically unattractive. AFO can correct foot drop, but if patients wear an AFO for a long time, it can produce negative effects such as ankle contracture and limitation of mobility (Mulroy et al., 2010). To supplement these problems, a many taping method is used for gait rehabilitation in patients with stroke. Kim et al. reported that muscle facilitation, gait ability, and balance function were improved after application of kinesiology taping on the tibialis anterior in patients with stroke (Kim et al., 2014). Bae et al. showed that static balance was improved in stroke patients with foot drop when applying lower-leg kinesiology taping (Bae et al., 2015). In addition, a mechanical taping method is applied to musculoskeletal and nervous system diseases. Lee et al. reported pelvic angle and musculoskeletal diseases around lower lumbar was decreased after Anterior Pelvic Tilt Taping which is mechanical taping method in office worker with slump sitting (Lee and Yoo, 2011). Lee et al. proved that Posterior Pelvic Tilt Taping decreased pelvic angle and sacral horizontal angle and have a positive effect on medical buttock pain (Lee and Yoo, 2012).

Taping methods have been used for gait rehabilitation in stroke patients, but most often taping is applied to the muscles. This study used ankle eversion taping, a mechanical method to correct foot drop. The purpose of this study is to assess the immediate effects of applying ankle eversion taping using kinesiology tape in patients with foot drop after stroke. And this study compared and analyzed ankle eversion taping, placebo taping, and no taping to prove the effects of ankle eversion taping.

2. Materials and methods

2.1. Participants

Although 21 subjects were recruited, six failed to meet inclusion criteria due to refusal to participate and not meeting inclusion criteria. Fifteen subjects met the inclusion criteria for the study. Subjects were recruited from Dalgubul rehabilitation center. All subjects provided informed, written consent prior to enrollment in the study. The protocol for this randomized cross-over design study was approved by the Research Ethics Committee of Daegu University (1040621-201609-HR-017-08). Subjects were required to meet the following criteria for inclusion in the study: (1) Index stroke > six months prior in women or men with foot drop (equinovarus deformity), (2) Brunnstrom's stage of motor recovery for the affected lower limb range of 3–5, (3) residual hemiparetic gait deficits, operationally defined as reduced stance phase in the paretic leg and ambulatory with or without any assistive device (Macko et al., 2005), (4) ability to understand and follow simple verbal instructions, (5) independent gait ability to walk at least 15 m without assistance, (6) no disability in visual, auditory, and vestibular organs, (7) no history of orthopedic diseases, such as

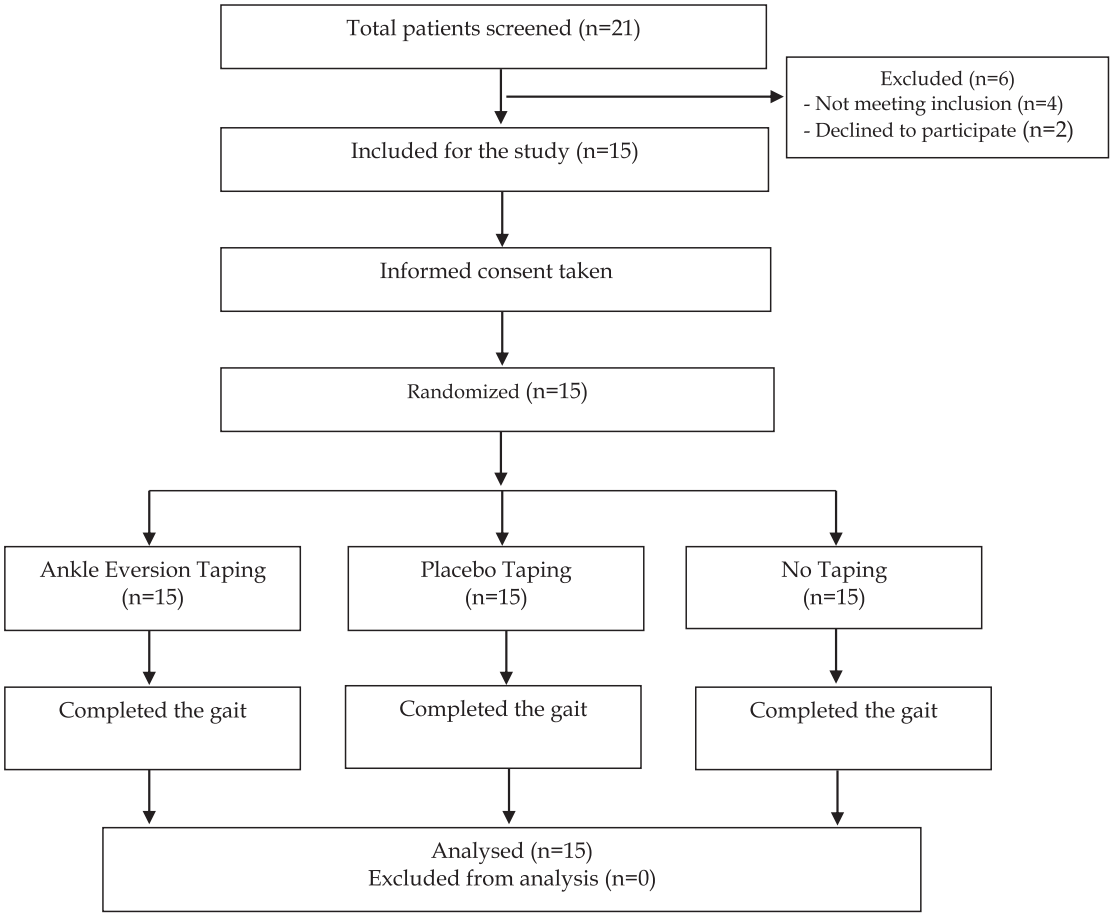

Fig. 1. Study flowchart.

contracture, fracture, or arthritis in lower limbs, and (8) a Mini-Mental State Examination score greater than 24/30 (Folstein et al., 1975). Exclusion criteria were as follows: (1) neurological problems other than stroke that would interfere with gait and balance control, (2) pain, limited motion, or weakness in the non-paretic lower extremity that affected performance of daily activities (by self-report), and (3) allergy to the Kinesiology tape or having the taping side effects such as skin redness.

2.2. Sample size calculation

The sample size for this study was calculated using the G* Power program 3.1.0 (G power program Version 3.1, Heinrich-Heine-University Dusseldorf, Germany). Based on the data from the pilot study, the estimated sample to obtain a power at 0.09 with a chosen five percent at significant level. This resulted in a sample size of 15 subjects being required.

2.3. Study design

A cross-over randomized design was used. Each subject underwent each intervention in a random order. Subjects were randomly assigned to an ankle eversion taping, placebo taping, and no taping. For randomization, sealed envelopes were prepared in advance and marked inside with A, B or C representing an ankle eversion taping, placebo taping, and no taping, respectively. Using the procedure described above, three interventions were applied in random order and gait of each intervention was evaluated.

To eliminate the effect of tearing off the taping, a 10 min break was given between ankle eversion taping and placebo taping intervention. This randomization was performed by a third party unaware of the nature of the study. Subject characteristics and all outcome measures obtained before and after treatment were assessed by Physician 1, who was blinded to treatment allocations. Interventions were performed in a closed room by Physician 2, who was not involved in subject assessment. Both physicians were instructed not to communicate with subjects about study goals or treatments and had >10 years of experience with kinesiology taping for each tape condition.

2.4. Outcome measure

Gait ability was assessed by the GAITRite System. All of the measurements were performed immediately after the intervention. The participants did not receive any other therapeutic interventions during the study period.

1) GAITRite System

A GAITRite system (GAITRite, CIR Systems Inc., USA) measured the spatiotemporal variables of gait (walking speed, walking cycle, affected side stance phase, stride length) and the symmetry index

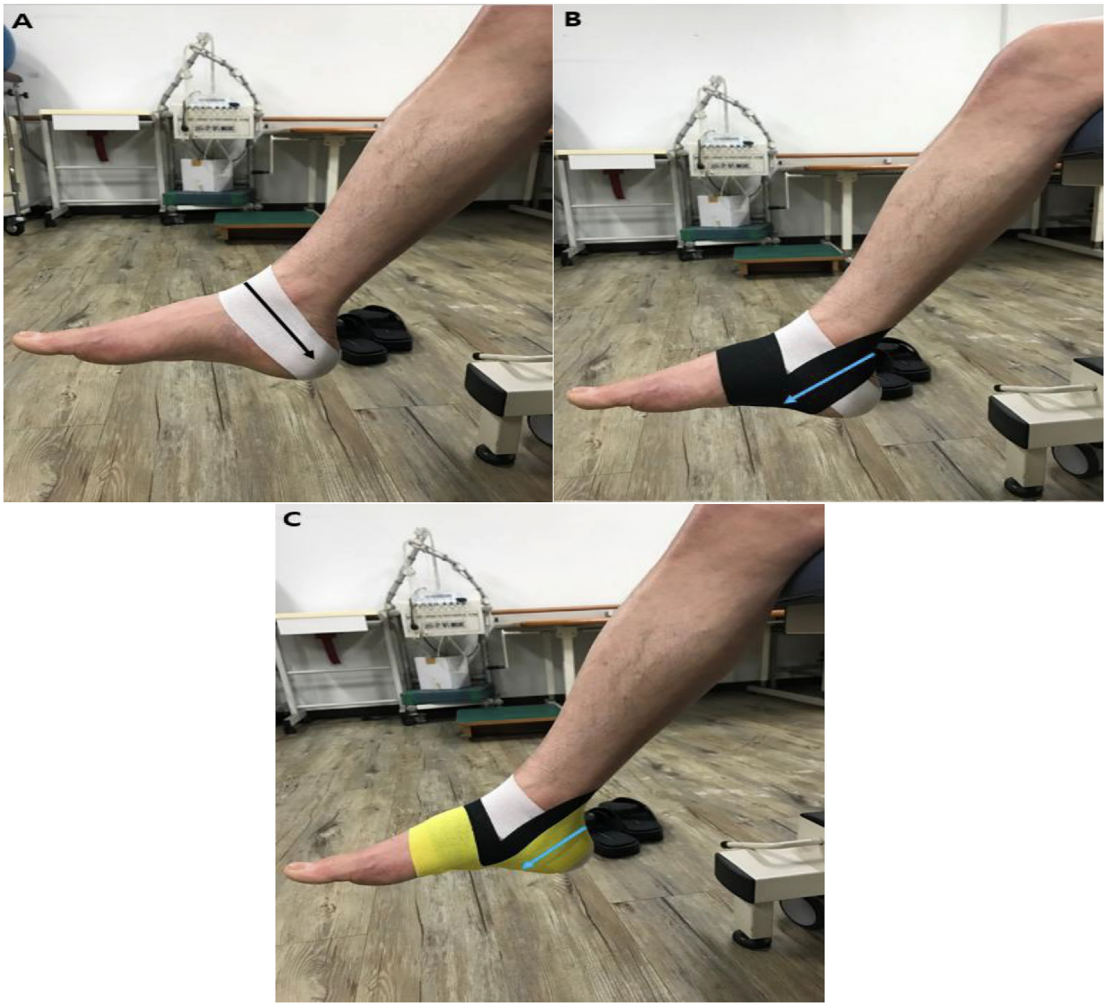

Fig. 2. Ankle eversion taping.

Fig. 3. Placebo taping.

(stance phase, stride length). The standard GAITRite walkway contained six sensor pads encapsulated in a carpet with an active area of 3.66 m in length and 0.61 m in width. As the subject walked along the walkway, the sensors captured each footfall as a function of time and transferred the gathered information to a personal computer for processing into footfall patterns (McDonough et al., 2001). Subjects performed three trials, and the average was calculated for analysis. The measured gait variables are gait velocity (cm/s), step length (cm), stride length (cm), H-H base support (cm) and cadence (steps/m). All measured variables were measured as mean of the paralyzed side and the non-paralyzed side.

Step length is the linear distance between two consecutive points of contact with the ground by the right and left feet, whereas stride length is the linear distance between two consecutive points of contact with the ground by the same foot. Gait velocity is obtained by dividing the distance traveled by the ambulation time. It is expressed in centimeters per second (cm/s). H-H base support refers to the vertical distance between the heel of one foot to the proceeding line of the other foot. Cadence is defined as steps per minute.

2.5. Kinesiology tape application

1) Balance taping for Ankle Eversion

This study used kinesiology tape (Kinematics Tex, SPOL Co., Ltd., Seoul, Korea) with elasticity. The patient is seated in a comfortable position on a high table that is enough to prevent the feet from touching the ground, while the therapist applies the tape on the damaged ankle stretched with a tension of 30–40%.

Ankle eversion taping consists of two stages (Lee and Choi, 2016). The first stage is posterior talar gliding taping to increase the dorsiflexion of the ankle. This taping sets the patient's ankle in a slightly dorsiflexed state and begins from the front part of talus, passes around both sides of malleolus and wraps up the calcaneus.

The second stage is eversion taping for the eversion of ankle. It sets the patient's ankle in a slightly eversed state and begins from 5 cm above the outer malleolus, passes around the back side, down the inner malleolus, and wraps up the sole from the inside to outside. This stage applies the kinesiology tape twice, with approximately 50% overlapping. Since the patients have a disability in the equino-varus deformity of foot due to stiffness of plantar flexors, weakness of dorsiflexors and increased spasticity, taping is done twice to reinforce the inversion of ankle through eversion taping application (Fig. 2).

2) Placebo Taping

Placebo taping can be classified into two stages (Lee and Lee, 2015). The first stage begins with the inner malleolus and is applied up to the inner middle point of the lower limb. The second stage begins from the outer malleolus up to the outer middle point of the lower limb (Fig. 3).

2.6. Statistical analysis

Statistical analysis was performed using SPSS (SPSS Inc. Released 2009. PASW Statistics for Windows, Version 18.0. Chicago: SPSS Inc.). The Shapiro-Wilk test was used to check normality of the outcome variables. Subject general characteristics were analyzed using descriptive statistics and results are reported as means and standard deviations. One-way repeated ANOVA was used for the group analysis, and the post-hoc Tukey test was used to assess differences between the groups. Null hypotheses of no difference were rejected if p-values were less than .05.

3. Results

A CONSORT flow diagram is provided in Fig. 1, and a summary of clinical and demographic features of the 15 study subjects in Table 1. The characteristics of the study subjects before and after each intervention are shown in Table 2. All subject did not have skin redness on taping and there were no side effects.

Table 1
General characteristics of the subjects (n = 15).

Variable	Mean ± SD
Age (year)	62.93 ± 6.28
Height (cm)	164.27 ± 10.71
Weight (kg)	63.00 ± 14.68
Sex (male/female)	8/7
Hemorrhage/Ischemic	4/11
Brunnstrom's stage (3/4/5)	3/8/4
Mini-Mental State Examination score	26.66 ± 0.81
Time since onset (year)	7.77 ± 1.89

SD, standard deviation.

Table 2
Comparison of the velocity, step length, stride length, Cadence and H-H base support among the three condition (n = 15).

	Mean ± SD			F	*p*
	No Taping	Placebo Taping	Ankle Eversion Taping		
Velocity (cm/s)	54.27 ± 18.35	61.33 ± 18.25	71.03 ± 21.89	16.590	0.000
Step Length (cm)	36.52 ± 7.15	39.63 ± 8.27	42.17 ± 8.66	16.264	0.000
Stride Length (cm)	73.62 ± 14.24	79.59 ± 16.51	84.83 ± 17.35	15.658	0.000
Cadence (steps/m)	88.27 ± 18.35	91.86 ± 14.81	100.19 ± 16.92	10.340	0.000

Velocity, step length, stride length and cadence under the ankle eversion taping conditions significantly increased ($p < 0.05$) compared to the placebo and no taping conditions (Table 2, Fig. 4).

4. Discussion

This study was performed to evaluate the immediate effect of the gait ability in stroke patients with foot drop after applying ankle eversion taping. Gait ability in stroke patients with foot drop significantly improved after using ankle eversion taping. This supports our hypothesis that ankle eversion taping can decrease foot drop and increase gait ability.

Gait velocity, step length, stride length, and cadence significantly increased in ankle eversion taping group compared to the other two groups (placebo and no taping condition).

Our findings suggest that there are several mechanisms of ankle

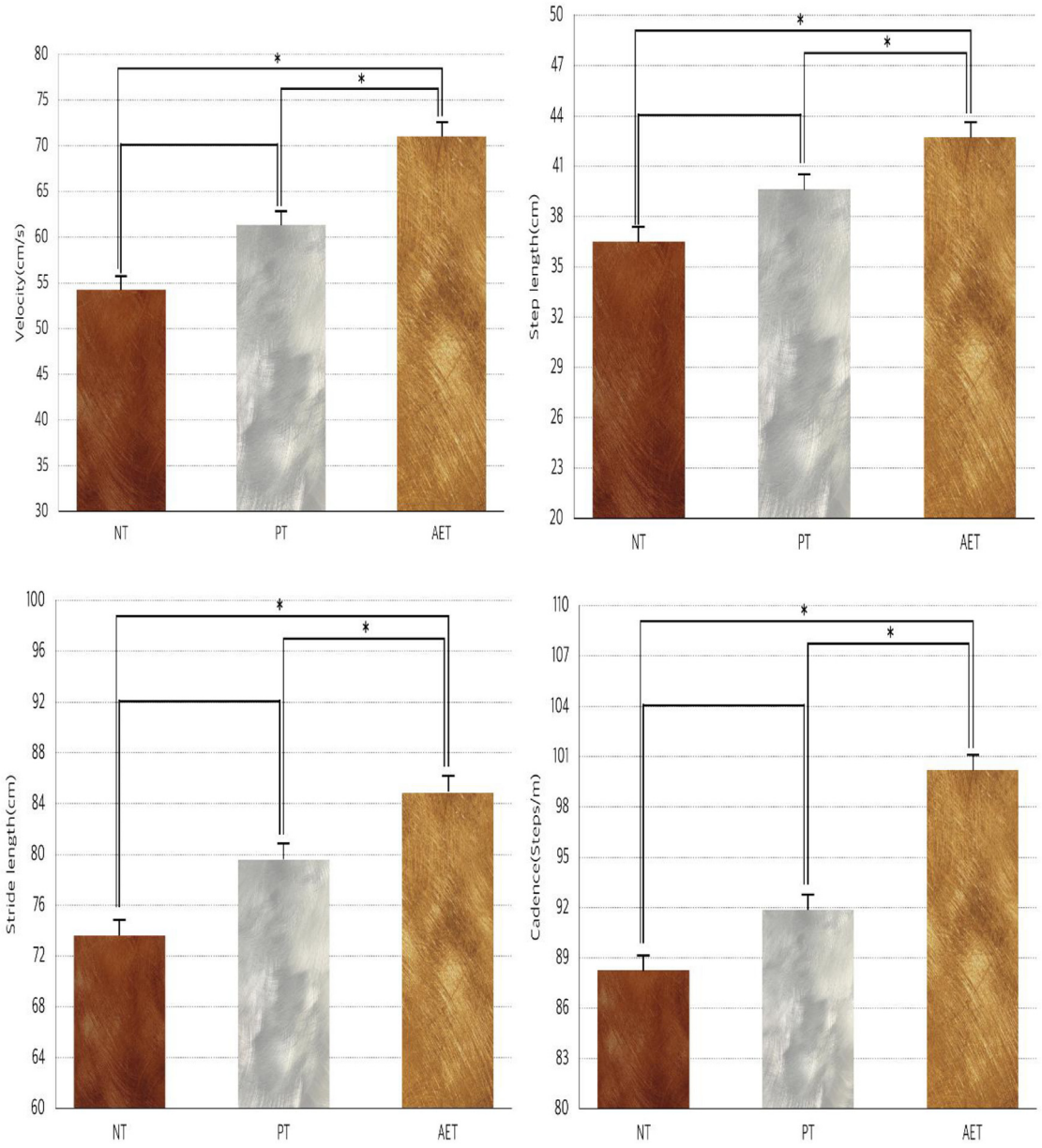

Fig. 4. Comparison of the velocity, step length, stride length and cadence among the three different taping methods (*p < 0.05). AET, Ankle Eversion Taping; PT, Placebo Taping; NT, No Taping.

eversion taping that improve gait ability in stroke patients with foot drop. First, we used a mechanical taping method. Mechanical taping is not a general method that tapes the muscles. Many studies report that taping can correct posture due to a mechanical effect. Han et al. proved that rounded shoulder posture was immediately corrected using kinesiology taping with 30–40% tension (Han et al., 2015). Lee et al. reported that posterior pelvic tilt taping with 30–40% tension could decrease the anterior pelvic tilt in women who usually wear high heels (Lee et al., 2014). Stroke patients with foot drop commonly showed plantar flexion and inversion deformity caused by stiffness of plantar flexors and weakness of dorsiflexors. For this reason, this study applied ankle eversion taping that is two kinds of mechanical taping to improve dorsiflexion and eversion. In our study, we used posterior talar gliding taping to make an ankle dorsiflexion, and eversion taping that covers from the inside foot out to make an ankle eversion. Lee used these methods (Lee and Choi, 2016) and proved ankle eversion taping could decrease ankle pain, improve ankle flexibility, and increase dynamic balance using kinesiology taping in patients with ankle inversion sprain. Second, the tape used by Lee is elastic kinesiology taping, not rigid taping, which commonly uses inelastic tape. Rigid taping is used to protect joints and muscles (Thelen et al., 2008), but it can limit ankle mobility and ankle contracture as much as AFO (Thelen et al., 2008). This study corrected the foot drop deformity by applying kinesiology tape with 30–40% tension and allowed some movement of ankle in elastic range. This study applied ankle eversion taping to minimize limitation of ankle and prevent foot deformity caused by foot drop. Our study supposes that ankle eversion taping corrects foot deformity and supports foot posture due to the mechanical effect of foot, so gait parameters differed significantly.

Finally, our results may be related to somatic sensation. Somatic sensation problems, especially proprioception and postural sensation, are common in stroke patients (Leibowitz et al., 2008). Kinesiology taping improves proprioception and postural sensation. Long et al. reported that kinesiology taping could enhance sensory stimulation by increasing proprioception at the ankle and foot (Long et al., 2017). Konishi proved tactile stimulation could relieve muscle weakness caused by decrease of a afferents and suggested using tactile stimulation by kinesiology tape to strengthen muscle activity (Konishi, 2013).

The application of ankle eversion taping that uses kinesiology tape instantly increased the walking ability of stroke patients with foot drop. This study showed that kinesiology taping method is effective to increase gait function after stroke. However, this study has some limitations. First, we could not assess or correct for the learning effects of the taping. Even though we randomly gave intervention to the subjects and let them take a rest between each intervention during ten minutes, we cannot ascertain that learning effect was totally excluded. Further research should consider additional outcomes, longer treatment, and continued observation. The study to compare kinesiology tape with AFO and FES, which is the method for decreasing ankle drop, is needed.

5. Conclusion

We conclude that the application of ankle eversion taping that uses kinesiology tape instantly increased the gait ability of chronic stroke patients with foot drop. However, more research is necessary to identify the long-term effects of the ankle eversion taping.

Declaration of interest

There are no conflicts of interest regarding this research.

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