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Research Article

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Immediate Effects of Ankle Eversion Taping on Balance and Gait Function in Patients with Chronic Stroke: A Randomized Controlled Trial

Hye-In Bae, PT, MS · Myeong-Ho Lee, PT, MS[1] · Myoung-Kwon Kim, PT, PhD[2†]

Rehabilitation Center, Gyeongbuk Reginal Rehabilitation Hospital
[1]Department of Rehabilitation Sciences, Graduate School, Daegu University
[2]Department of Physical Therapy, College of Rehabilitation Sciences, Daegu University

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| Abstract |

PURPOSE: This study examined the immediate effects of applying ankle eversion taping using kinesiology tape in chronic stroke patients—design: a randomized cross-over trial.

METHODS: Seventeen stroke patients underwent three interventions in random order. The subjects were initially assigned randomly to an ankle eversion taping, placebo taping, or no taping for each intervention. Ankle eversion taping was used for mechanical correction and was involved in ankle dorsiflexion and eversion. The tape was stretched by 30-40%. Placebo tapping was applied in the same form as eversion tapping but was not stretched. The balance ability was assessed using the Y-balance test. The gait ability was assessed by maximum foot pressure and time of stance phase, and gait speed was assessed using a 10 m walk test (10MWT). All measurements were performed immediately after the intervention.

RESULTS: The results showed that the dynamic balance and stance phase time in chronic stroke patients was improved after ankle eversion taping. The ankle eversion taping conditions increased significantly ($p < .05$) compared to the placebo and no taping conditions.

CONCLUSION: The application of ankle eversion taping that uses kinesiology tape instantly increased the gait ability of chronic stroke patients. On the other hand, more research will be needed to identify the long-term effects of ankle eversion taping.

Key Words: Ankle eversion taping, Gait, Stroke

Ⅰ. Introduction

Stroke is one of the most dangerous conditions secondary to cerebrovascular disease or cerebral blood supply problems, which can cause death or severe disability. Hence, continuous rehabilitation is important for

†Corresponding Author : Myoung-Kwon Kim
skybird-98@hanmail.net, https://orcid.org/0000-0002-7251-6108

minimizing neurological disorders caused by nerve recovery immediately after cerebral ischemia or cerebral hemorrhage [1].

Although the survival rate from stroke has been increasing significantly in recent decades as medical technology has developed, most stroke patients live with various disabilities, such as hemiplegia, and require long-term nursing and rehabilitation treatment. The functional changes caused by stroke are accompanied by language disorders, behavioral patterns, and memory and emotional changes [1]. Moreover, there is great difficulty in controlling posture due to these abnormalities in motor and sensory functions, such as muscle weakness, paralysis, and spasticity [2]. Lower extremity disorders and changes in gait patterns, and difficulties, such as abnormal exercise timing and balance disorders, increase the risk of falls and deterioration of daily activities and mobility [3]. In addition, difficulty in walking and postural sway increase [4], and the limit of stability is reduced.

Most stroke patients suffer from a loss of control of the central nervous system on the paralyzed side, resulting in excessive muscle tone, such as weight-bearing and balance problems, spasticity, excessive tendon reflexes, dissonance between the agonist and antagonist muscles, simultaneous contraction of synergistic patterns, and rigidity. Hemiparetic gait occurs due to loss of proprioception and balance [5]. Therefore, one of the great goals of the rehabilitation of stroke patients is to restore the balance and gait ability [6].

In the standing posture, the center of pressure of the ankle joint moves forward and backward, left and right. The forward and backward movements are the dorsiflexors and plantar flexors of the ankle joint, and the left and right movements are controlled by the inversion and eversion muscles [7]. The ankle joint absorbs shock when walking, and the ankle movement increases energy efficiency, making walking easier [8]. The main cause of movement restrictions of the ankle joint is weakness and spasticity of the surrounding muscles. Another cause is that restricted movement for a long time alters the mechanical properties of the muscles and connective tissue around the ankle, resulting in decreased movement [9]. If the joint movement range of the ankle decreases, the gait ability decreases due to an imbalance in walking factors, such as walking speed and stride length during walking [10].

The ankle of stroke patients is caused by the spasticity of the plantar flexor muscles and weakness of the dorsi flexor muscles, causing the pressure distribution to move in the anterior lateral direction and foot drop [10]. In addition, the asymmetry of foot pressure on the non-affected side worsens, and the stance phase weight-bearing time decreases owing to the instability of the ankle joint, muscle weakness, loss of coordination, and disorders, such as reflex ability [11]. Therefore, stroke patients show reduced movement of the center of gravity and instability of the bearing surface in standing and gait [12], and the ability to stabilize the posture in sudden fluctuations because of problems in weight bearing capacity and balance response, balance, and gait difficulty [13].

Normal gait has temporal and spatial symmetry, and the difference in vertical force and temporal parameters between the lower extremities is less than 6% [14]. The gait pattern of stroke patients shows a slow gait speed and gait cycle, a difference between the stride length of the affected and unaffected sides, difficulty in weight-bearing during the short stance phase, and a relatively long swing phase on the affected side [15,16]. Approximately 55.5% of chronic stroke patients showed significant asymmetry [17].

Spasticity of the plantar flexor muscle of the ankle joint during hemiplegic gait makes it difficult for the heel to touch the ground, leading to contact with the forefoot and shortening the stance phase by allowing the foot or toe to step. Hemiplegic patients also show asymmetry during sitting, standing, and gait [18]. Even in the functional

movement performance, the movement is performed with more weight on the non-affected side, and 60–70% of the total body weight is supported by the non-affected side [19]. As a result, the gait speed is reduced, and the spatiotemporal variables are changed due to unstable standing posture, balance ability and quality deterioration of gait pattern, reduced adaptability, and impaired control of the lower extremities [20]. Problems in the equilibrium response to external fluctuation are encountered, and along with an unbalanced standing posture, balance and posture control are difficult and asymmetric posture, abnormal body balance, and a loss of weight transfer ability [21].

In several studies, asymmetry of gait has been reported as an important characteristic of stroke patients and is reported to be a vital function in determining the gait control ability [22]. Therefore, the symmetry of gait speed, weight support of the lower extremities, and ability to move weight have become important goals for stroke rehabilitation [23]. According to Darak et al. [24], the gait asymmetry increases as the asymmetry in weight bearing becomes more severe, and a correlation between the gait asymmetry and speed was also found.

Representative clinical evaluation tools for such balance, posture control, and gait effects include Timed Up and Go test, 10-meter walking time test, Burg balance scale, and plantar pressure measurement test, all of which the test-retest and inter-examiner reliability were reported to be relatively high [15,25].

Taping is a treatment method that improves the joint and muscle movement by winding or attaching tape to the muscles of the body and each joint and is a method that is gradually increasing in use because of its easy application, immediate effect, and low side effects and risks [26]. Taping transmits the skin receptivity signal more strongly, improves the proprioceptive sensation, and promotes the correct alignment of the joint, thereby improving joint stability, leading to an improvement in gait and balance [27]. Among them, Kinesio taping is thin and has fewer side effects, such as allergies, and therapeutic effects include pain reduction, muscle strength enhancement, improvement of blood and lymph circulation, and reduction of dislocated joints caused by relieving abnormal muscle tension. Previous studies showed that Kinesio taping is used as a supplementary treatment for rehabilitation with a positive effect on pain and gait patterns [28]. In a previous study related to kinesio taping, taping applied on the affected side of stroke patients effectively improves typical asymmetric gait and gait speed [29]. In addition, Jaraczewska et al. [30], the taping method applied to the upper extremities of stroke patients, could facilitate muscle function and support joint structure, maintain body alignment, and provide feedback to proprioceptive sensations. In previous studies, however, selective taping of weak muscles and joints in stroke patients has been applied, and studies of taping related to movement are insufficient. In addition, few studies have shown that the focus was only on the static balance by supporting the joint structures and that the lack of gait quality can be improved. Therefore, this study applied ankle eversion taping as a mechanical correction method for chronic stroke patients. The effect of ankle eversion taping on the balance and gait function in chronic stroke patients was investigated by comparing and analyzing the results of ankle eversion taping, placebo taping, and no taping, and a more effective treatment method is provided for actual clinical practice.

Ⅱ. Methods

1. Participants

This study was conducted on 17 patients who were fully aware of the purpose of the study and obtained voluntary consent after hearing the explanation of the experimental procedure among 20 patients hospitalized in a rehabilitation hospital in Daegu and receiving exercise therapy. The reasons for exclusion were one refusal and two deteriorating health conditions. The study was conducted after receiving

approval from the Daegu University Institutional Review Board (approval number: 1040621-201811-HR-011-02).

The specific screening criteria are as follows: stroke patients diagnosed with stroke by a specialist and who have become hemiplegia and who have passed six months or more after onset to minimize the possibility of natural recovery [31]; patients with an initial bug balance test score of 33 or more [28,32]. The exclusion criteria were as follows: those with musculoskeletal disorders that can affect the experiment and patients with skin allergies caused by taping.

2. Experimental Method

A third party unaware of the study content performed the randomization. Ankle eversion taping, placebo taping, and no-taping were assigned randomly to 17 stroke patients, and pre-sealed envelopes were prepared for random extraction, and ankle eversion taping, placebo taping, and no-taping were marked as A, B, and C inside. Using the procedure described above, three interventions were applied in random order. Sufficient rest of at least 24 hours was allowed between each intervention.

1) Ankle Eversion Taping

Elastic kinesio tape (Kinematics Tex, SPOL Co., Ltd., Seoul, Korea) was used. The patient sat comfortably on a chair so his feet did not touch the floor. The therapist stretched the tape by 30–40% and attached it to the ankle on the affected side. The ankle eversion taping consisted of three steps [33].

The first step was to perform glide taping behind the talus bone to increase the dorsiflexion of the ankle. This taping started at the front of the ankle with the patient's ankle slightly dorsi flexion, passed both sides of the malleolus, and covered the calcaneus (Fig. 1-A).

The second step was taping for ankle eversion. With the patient's ankle slightly eversion, taping started at the top of the lateral malleolus 5 cm. The back side was then wrapped. The tape was passed under the medial malleolus and wrapped from the inside to the outside of the soles (Fig. 1-B).

For this step, Kinesio tape was applied twice, with approximately 50% superimposed (Fig. 1-C).

2) Placebo Taping

For the placebo effect, the therapist attached the tape to the ankle on the affected side without stretching it. Placebo taping consisted of three steps.

The first step was taping without gliding behind the talus or increasing the dorsiflexion of the ankle. This taping started at the front of the ankle without ankle dorsiflexion and covered both sides of the malleolus to cover the calcaneus (Fig. 2-A).

The second step was to start above the lateral malleolus 5 cm without ankle eversion. The tape was then wrapped around the back side, passed under the medial malleolus, and wrapped from the inside to the outside of the soles (Fig. 2-B).

For this step, Kinesio tape was applied twice, with approximately 50% superimposed (Fig. 2-C).

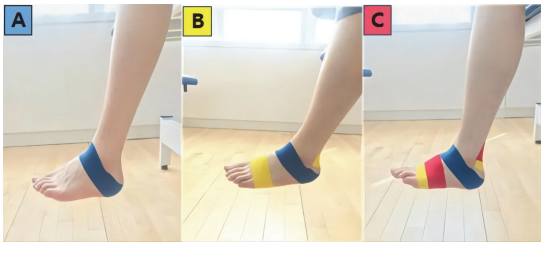

Fig. 1. Ankle eversion taping.

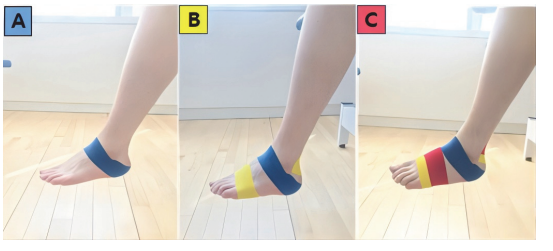

Fig. 2. Placebo taping.

3. Measurement Method

1) Dynamic Balance Test

A Y-balance test was used for the dynamic balance test. At the center, where three lines were drawn at 120° intervals, the subject stood supported with the affected side leg and stretched the leg as far as possible in each direction to evaluate the record. The three lines represent the anterior, posteromedial, and posterolateral in each direction around the center. All measurements were measured three times for each subject, and the average value was used for the results. The intra-examiner reliability ranged from r = .85 to r = .89, and the inter-examiner reliability ranged from r = .97 to r = 1.00 (Grzeda, 2013).

2) Gait Speed

A 10 m walking test was performed to test the walking ability. The 10MWT was performed on a walking path of 14 m flat ground. The walking time of the first 2 m and the last 2 m was not measured to increase the accuracy of the measurement, and the walking time of the intermediate 10 m section was measured in .01-second units. After one practice session, the average value was obtained by repeating the measurements three times. In the test-retest method of this tool, the intraclass correlation coefficient was high at ICC = .95–.96 [34].

3) Gait Symmetry

A pressure platform foot pressure meter (Zebris FDM, Zebris, Germany) that can be recorded and analyzed electronically was used to measure the walking symmetry of the subject. The reliability of this tool was high at ICC = .86 [35].

The subjects stood barefoot in front of the foot pressure measuring device, relaxed both arms next to the body, and walked alternately for two minutes, and stored the gait five times in the middle as a value. The asymmetry of the foot pressure distribution was obtained using the formula developed by Robinson et al. based on the stance phase [36]. The formula to calculate the foot pressure asymmetry index of the left and right soles is as follows. The gait symmetry was determined by the contact time of the stance phase of the affected side.

4. Statistical Processing

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, Dusseldorf, Germany) [37,38]. Based on the data from the pilot study, the estimated sample size was obtained from a power of .08 and a significance level of 5%. This resulted in a sample size of 16 subjects being required. Twenty participants were recruited to account for potential dropouts.

The data were analyzed by placing 17 patients randomly into the following three groups: ankle eversion taping, placebo taping, and no taping. Statistical analysis was analyzed using the SPSS (statistical package for the social sciences) version 22.0 for window software (SPSS Inc., Chicago) program.

Descriptive statistics were used for the general characteristics of the study subjects, and a chi-squared test was used for the homogeneity test of the subjects between interventions. A Shapiro–Wilk Test was performed to verify the normality of the measured data. One-way repeated ANOVA was used to examine the differences between interventions, and an LSD test was used as a post hoc test to determine the differences within the groups. The statistical significance level (a) was set to .05.

Ⅲ. Result

1. General Characteristics of Study Subjects

In this study, 17 patients who were admitted to a rehabilitation hospital located in Daegu Metropolitan City and receiving exercise therapy were selected. Table 1 lists the general characteristics of the subjects.

Table 1. General and common clinical characteristics of the participants (n = 17)

Variable	
Age (year)	55.06 (6.39)[1]
Height (cm)	168.16 (7.61)
Weight (kg)	65.94 (8.47)
Sex (male/female)	14 / 3
Hemorrhage / Ischemic	10 / 7
Berg Balance Scale	42.82 (2.70)
Time since onset (month)	18.65 (9.43)

[1] Mean (± standard deviation).

2. Comparison of Dynamic Balance between Interventions in Each Direction

Table 2 shows the difference in dynamic balance according to each taping application. In the anterior direction, there was a significant difference between the ankle eversion taping and the placebo taping, and there was also a significant difference between the ankle eversion taping and no taping. In the PM direction, there was a significant difference between all groups. In the PL direction, there was a significant difference only in the ankle eversion taping and no taping.

Table 2. Comparison of dynamic balance between interventions in each direction (unit: cm)

	NT	PT	AET	F	P
A	43.47 (11.66)[1]	43.53 (11.05)	59.12 (12.03)	4.237	.020*
PM	30.41 (11.34)	42.12 (14.25)	47.53 (15.85)	10.298	.000*
PL	42.71 (10.33)	48.82 (9.15)	53.24 (12.09)	6.700	.003*

[1] Mean (± standard deviation).
A: Anterior
PM: PosterioMedial
PL: PosterioLateral
NT: No taping
PT: Placebo taping
AET: Ankle eversion taping
* Statistical significance $p < .05$.

3. Comparison of the Gait Speed and Gait Symmetry between Interventions

Table 3 shows the difference in gait speed according to each taping application. The gait speed decreased on average according to the ankle eversion taping, but there was no significant difference, and the bilateral maximum foot pressure symmetry was similar.

A significant difference was noted in the stance phase in ankle eversion taping compared to no taping and placebo taping.

Ⅳ. Discussion

This study examined how the application of lateral ankle eversion taping immediately affects the dynamic balance and gait function of patients with hemiplegia caused by chronic stroke. Through this, the purpose of this study was to increase the understanding of the effect of ankle eversion taping on dynamic balance and gait function. A Y-balance test was performed to evaluate the dynamic balance ability, the gait speed was measured using a 10-meter gait test, and the quality of the gait function was measured for the contact time of the affected side stance phase and the symmetry of the maximum bilateral pressure. The dynamic

Table 3. Comparison of gait speed and gait symmetry between interventions

	NT	PT	AET	F	P
10MWT (unit: sec)	25.35 (14.92)[1]	25.19 (14.43)	18.19 (11.80)	1.496	.234
Maximum Pressure (unit: N/cm2)	35.72 (24.19)	33.69 (21.51)	22.75 (14.65)	1.967	.151
Contact time (unit: sec)	1.29 (.43)	1.28 (.33)	3.6 (.90)	28.830	.000*

[1] Mean (± standard deviation).
NT: No taping
PT: Placebo taping
AET: Ankle eversion taping
* Statistical significance $p < .05$.

balance and gait function were improved according to ankle eversion taping, and a significant effect was observed compared to the control group. These results are consistent with the hypothesis that ankle eversion taping has a significant effect on the balance and gait function in chronic stroke patients.

Previous studies that applied taping to stroke patients reported that the application of gluteus maximus taping on the affected side showed a significant difference in static balance [39]. An immediate effect was demonstrated for round shoulder posture correction using kinesio taping [40], and posterior pelvic tilt taping applied to women who wore high heels for a long time affects the reduction of the anterior pelvic tilt, which is also significant in reducing the pain of the sacroiliac joint [41].

In this study, the results before and after taping are as follows. First, the dynamic balance was significant in the Y balance test when the condition of applying ankle eversion taping was significant compared to the conditions of applying placebo tape and no taping ($P < .05$). posteriomedial side (PM) was significantly different in all three groups ($P < .05$), and the posteriolateral (PL) had no significant difference from the condition to which placebo taping was applied, but there was a significant difference from the group to which no taping was applied ($P < .05$). The affected-side taping applications in stroke patients influence balance improvement, positively affecting typical asymmetric gait and gait speed [29], and when applying kinesio taping to patients with multiple sclerosis, the results were consistent with previous studies showing an effect on the balance in the standing position [42].

Second, there was no significant difference in the comparison of gait speed between each intervention before and after taping. On the other hand, previous studies have reported that kinematic taping applications had a positive effect on the gait speed [43], and taping applications on ankle joints in patients with paraplegia significantly differed in gait speed [44]. A comparison of the gait speed between interventions showed that the ankle eversion taping group (18.19 ± 11.80) showed a reduced gait speed by 28.24% compared to the no-taping group (25.35 ± 14.92) and also had a positive effect of 27.79% on the gait speed reduction compared to using placebo taping group (25.19 ± 14.43). Although there was a positive effect on the decrease in gait speed, the effect was not significant. Previous studies showing significant improvement had more than one evaluation method, but only a 10 m walk test was measured in this study. In the future, it will be investigated better through an evaluation that can measure the gait speed in various ways. A comparison of the gait symmetry between each intervention revealed ankle eversion taping to have similar symmetry of both foot pressures to the placebo taping and no taping groups. A significant difference was noted in the stance phase time of the affected side compared to the placebo taping and no taping ($P < .05$).

In previous studies, taping provided somatosensory feedback, which is effective in postural control [45,46]. Ankle joint taping provided mechanical support and facilitated stimulation according to the application [47], improves proprioception, maintains joint alignment, improves stability through ligament reinforcement and restriction of excessive movement, and is effective in balance and gait [48,49]. In this study, various effects of taping also improved ankle stability, allowing weight to be further supported by the affected-side leg from the stance phase, and it is thought that the ankle inversion pattern was reduced.

The study results on foot pressure symmetry in the stance phase did not show significant values due to several limitations. On the other hand, the ankle eversion taping (22.75 ± 14.65) had 36.31% better maximum pressure symmetry than no taping (35.72 ± 24.19) and 32.47% better than placebo taping (33.69 ± 21.51), but the difference was not significant. Therefore, basic data showing that applying kinesio taping is a useful intervention in chronic stroke patients with foot pressure asymmetry is meaningful for subsequent studies.

In summary, the positive effects on dynamic balance and stance phase were confirmed by securing ankle joint muscle length and increasing somatic sensory input by applying ankle eversion taping to stroke patients. Even placebo taping applied without stretching force can continuously contract the muscles through a sensory response through the skin adhesion of the tape and increase blood and lymph circulation to improve the motor function of the muscles [50]. According to Jaraczewska and Long [30], ankle eversion taping with the application of a stretching force had a more positive effect on the dynamic balance and gait ability of stroke patients than without stretching force.

A limitation of this study was that because only one of the various taping methods that can be applied to stroke patients was applied, the effects on the balance and gait function according to the taping method were not confirmed, and a comprehensive evaluation of the effect of ankle eversion taping on electromyography or other body parts was insufficient. In addition, the time for motor learning on the ankle joint stability and muscle activity may not be sufficient because only a cross-sectional study was conducted on the immediate effect of taping [51]. Furthermore, because only subjects who meet the criteria among chronic stroke patients were enrolled, there is a limit to generalizing the results to all stroke patients.

Future studies will need to revise and supplement these limitations to comparatively analyze the effects of kinesio taping application sites and methods and comprehensively analyze the effects of ankle taping on other body parts. The effect with time will need to be examined using a multi-faceted research method.

Ⅴ. Conclusion

This study examined the effects of ankle eversion taping on the dynamic balance and gait function by comparing the effects of ankle eversion taping, placebo taping, and no taping in stroke patients.

The anterior (A) of the dynamic balance showed effective improvement with ankle eversion taping compared to the placebo taping and no taping groups, and the posteriomedial (PM) had a significant difference between all three conditions.

The posteriolateral (PL) did not have a significant difference between ankle eversion taping and placebo taping, but there was a significant difference compared to no taping.

There was no significant difference in the comparison of gait speed between each intervention.

In comparing the gait symmetry between each intervention, ankle eversion taping had a positive effect on the symmetry of the foot pressure compared to the placebo taping and no taping, but there was no significant difference.

The stance phase contact time of the affected side differed significantly with ankle eversion taping than in the placebo taping and no taping groups.

The ankle eversion taping in stroke patients influenced the increase in dynamic balance evaluation distance and the stance phase contact time during gait, and it can be considered an effective clinical treatment by inducing active participation in rehabilitation programs for their rehabilitation.

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