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Influence of Kinesio Taping for Stroke's Ankle Joint versus Ankle-Foot Orthosis on Muscle Stimulation and Gait Ability in Stroke's Foot Drop

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Abstract

The aim of this study was to evaluate Kinesio Taping can improve muscle activity, joint angle, gait ability in patients with stroke suffering foot drop. Total 25 patients were selected as subjects of this study and were divided into two groups. Experimental group participated in the Kinesio Taping on ankle joint with treadmill walking, while control group wore AFO on ankle joint with treadmill walking for 4 weeks, 30 minutes per session, three times per week. In two groups, muscle activity was measured using the EMG, joint angle was measured using the Dartfish program, and gait ability was measured using the 10meter walking test before training and after 4-week training. Experiment group showed a statistically significant improvement muscle activity, joint angle, gait ability compared to control group in 4 week. Application of Kinesio taping has a more positive effect on the muscle activity, joint angle, gait ability than AFO of the patients with stroke suffering foot drop.

***Key words**: stroke, rehabilitation, gait, foot drop*

1. Introduction

Stroke is a central nervous system disease, which is caused by sudden cerebrovascular ischemia or hemorrhage that impedes a smooth blood supply to the brain tissue, resulting in partial damage to brain function that causes function impairment [1]. According to a report by the World Health Organization, stroke has the third highest mortality rate in advanced countries, and 15 million people experience impairment each year [2].

Although approximately 80% of the patients are able to walk after a stroke, they show an abnormal walking pattern due to function impairment [3]. Patients with stroke show walking characteristics that have no selective movement, while the gait cycle is asymmetric and inefficient due to synkinesis [4]. Moreover, 84% of the patients with stroke develop contracture in more than one joint, among which 76%havecontracture in the ankle joint [5]. The patients with stroke also show walking characteristics where selective muscle control is difficult due to atonic or spastic paralysis, showing synkinesis as well as inefficient and asymmetric abnormal walking [4].

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The ankle joint supports the body through the collaborative action of muscle function of the lower limb during the weight-bearing process; it provides sensory information through tactile sensation of the sole in physical motion; and it stimulates sensory feedback of posture maintenance [6]. Since the ankle is in charge of the first-stage of balancing control upon posture disturbance, and shock absorption for balancing and walking, strengthening the muscles surrounding the ankle joint and enhancing its range of motion are essential for correct physical control ability and walking ability [7]. The unstable ankle of patients with stroke impedes the walking motion; stable ankle control during walking is critical for a normal walking pattern [8].

Foot drop are common symptoms that appear to CNS (central nervous system) injury, such as stroke and spinal cord injury in a patient. Foot drop is caused due to weakening of the ability to control the dorsiflexor of the ankle. Also it is shown dorsal flexion of the ankle joint due to the degradation of the calf muscles. As a result, it has a negative impact on the speed and quality of gait. Foot drop in patients with stroke is caused by weakening muscle strength and ankle-joint instability [9]. In particular, patients with stroke who have foot drop symptoms show ankle joint drag in the swing phase and have difficulties in heel strike in the early stance phase. In order to avoid ankle drag, they tend to show an abnormal walking pattern, such as excessive hip joint flexion or circumduction gait [10-13].

Taping around the ankle joint can accelerate mechanical support and stimulus according to the application method of winding or attaching [14, 15]. The attached taping enables stronger transmission of the skin receptive signal and stimulates improvement of the proprioceptive sense and the correct alignment of the joint, which contributes to joint stability enhancement to improve walking and balancing [16]. There are studies reporting that the taping, which functions as a walking aid by supporting the ankle joint, eventually enhances posture control ability and balance maintenance [17]. Richard [18] reported that applying taping on more than 50 patients with stroke produced satisfactory results as taping performed the role of a walking aid such as the ankle-foot orthosis (AFO). Currently, the AFO is widely used in clinics for the ankle stabilization of foot drop. The AFO has some advantages in that a patient can attach and detach it by themselves and wear diverse types of shoes, and it is easily washable [19,20]. However, the AFO does have shortcomings, such as an uncomfortable feeling of wearing something, having a fixed ankle joint even in unnecessary situations such as sitting or being in a motionless position, the necessary change of shoe size on the side wearing the walking aid, and having a fixed ankle during walking. These further weaken the surrounding muscles and they are often pointed out as a long-term drawback of the AFO [21]. Although the AFO showed positive effects on the gait velocity and stride length of the patients who have recently had a stroke, the positive effect of the plastic AFO is reported to disappear as time goes by [22].

Hence, this study attempts to examine the impact of Kinesio taping around the ankle joint on muscle activity, joint angle, and gait velocity among patients with stroke, and to compare the effects with the AFO, which is widely used in clinics. Moreover, the study aims at providing experimental data that can contribute to broadening the range of choice for patients with stroke by suggesting the possibility of using assistants other than the AFO.

2. Methods

2. 1. Subject and Intervention Procedure

The research subjects of this study consisted of 25 patients hospitalized in Hospital M in Seoul and Hospital C in Cheong-ju City in Korea, who were diagnosed with hemiparalysis due to stroke. After, sufficient explanation about the purpose and procedure of this study, spontaneous consents were obtained before their participation in this study. Concealed allocation was performed using a computer-generated randomized table of numbers created prior to the start of data collection by a researcher (control group 12 volunteers, experimental group 13 volunteers). The experiment proceeded by evenly dividing the sample into an experiment group where taping was applied around the ankle joint, and a control group who wore the AFO walking aid. The experiment group and the control group performed 30-minute daily treadmill walking three times a week, for a total of 4 weeks.

Among the patients who were diagnosed with stroke, who had no visual impairment or abnormalities in the vestibular organ and who depended on a walking aid, those who voluntarily consented to the research after listening to the explanation on the test materials were selected as the subjects. Those with replacement arthroplasty in the lower extremities, previous experience of a broken bone or falling, or extraordinary integumentary system disease were excluded from the research subject. The experimental group 13, control group 12 people experiment and measurement were conducted without dropouts.

2. 2.Assessment

In this study, a surface electromyogram of the Bagnoli EMG System (DelsysInc, Boston, MA,USA) was used for measuring the change of muscle activity in the lower limb for a total of four muscles; that is, the tibialis anterior (TA), the gastrocnemius (GCM), the rectus femoris, and the gluteus maximus. The sampling rate for collecting the electromyogram signal was set at 1024Hz. The measurement frequency range filter of the Bagnoli EMG System 30~500 Hz was used along with a notch filter at 60 Hz for the frequency band width, where two channels were used for recording. For the storage and analysis of the collected electromyogram signal, root mean square amplitude was analyzed using Acquisition and Analysis Software program (DelsysInc, Boston, MA, USA)

The electrode attachment site was shaved for minimum skin resistance and wiped with alcohol to remove skin oil. After the area was completely dried, two electrodes were attached to the skin. A small amount of electrolyte gel was applied to the site before the two electrode pads were attached to the skin.

For the TA, the electrodes were attached to the intersection point between the site that is four fingers below the tibia tuberosity, which is the most developed motor point between the origin and the insertion, and the site that is one finger lateral from the spine of the tibia. For the gastrocnemius, the electrodes were attached to the site that is five fingers below the lateral popliteus. For the proximal muscle of rectus femoris, the electrodes were attached to the site between the ASIS and the upper edge of the patella [25]. For the gluteus maximus, the electrodes were attached to the muscle belly, which is a central point of the line that connects between the inferior lateral angle of the sacrum and the greater trochanter [26]. When measuring the experimental group was not attached taping. The control group also did not wear AFO.

For the measurement of the joint angle, the Dartfish program (Pro Suite, Korea) was used, which is able to conduct kinematic motion analysis of hemiparalysis patients' walking. Dartfish captures the video clip that will be analyzed and compared by the user, and it is able to analyze performed exercise and its trace, as well as the velocity of the exercise. It can also assess the joint angle change, the velocity change of the performed exercise, the stride length change, the distance change, *etc.*, [27, 28].

In this study, the ankle angle of dorsiflexion was measured upon heel-strike of the paralyzed lower limb, while the ankle angle of the plantar flexion limb was measured upon toe-off. For better validity of the measurement, walking was repeated twice to calculate the average value. For accurate measurement, all the subjects received the test in their bare feet (*i.e.*, no running shoes).

In the 10-meter walk test, the start line and the end line were marked on the ground after adding two meters to each end in order to allow acceleration and a deceleration range, so the total walking distance became 4 meters plus the original 10 meters [29]. Using a stop watch, time was measured starting from the moment the research subject's foot passed the starting line until it passed the end line. The gait velocity was recorded in 1/100 second units. During the test, the research subjects were told to walk “comfortably at an ordinary daily walking speed”. The research subjects practiced once before the actual test. All the measurements were recorded three times and the average value was used. The 10-meterwalk test has very high test-retest reliability at 0.95 and an inter-rater reliability at 0.90 [30]. All measurements of this study, the researchers were directly tested.

2. 3. Intervention

The elastic Kinesio tape was attached to the skin without elongating the tape, while stretching the length of muscle to the maximum. The sites of tape application included the tibialis anterior (TA), the gastrocnemius, and the ankle joint (figure-of-eight taping) [23]. In order to improve the stability and supporting capacity ankle figure-of-eight shape manner it was applied to the ankle joint. For the TA, one end of the Kinesio tape with a width of 5cm and a length of 40cm was fixed between the big toe and the index toe on top of the foot of the patients' affected side. In the plantarflexion condition of the ankle, tape was attached to the lateral knee following the running direction of the muscle. For gastrocnemius, Y-shaped Kinesio tape was attached to the heel while stretching the ankle. In the maximum ankle flexion condition, the tape was attached following the running direction of the lateral and medial muscle of the gastrocnemius, which is slightly above the ankle. As for the ankle, Kinesio tape was attached in a figure-of-eight shape for ankle joint stability and support, referring to the research by Kwak [23].

For gait training using the treadmill, self-selected velocity was first measured under the weight-bearing condition. During the gait training phase, the velocity was set around 2–3 km/h in order to minimize the overlap effects of walking improvement from the treadmill exercise, where the velocity was determined according to the patients' ordinary walking ability, so they could feel most comfortable [24]. Even during treadmill gait, experimental group was applying the taping. The control group was performed to treadmill gait while wearing the AFO.

Patients in both the experiment group and the control group instantly stopped walking when they felt abnormal symptoms, such as fatigue or pain, after walking on the treadmill. Safety handles were located in the front and on both sides of the treadmill, and the patients were told to instantly grip the handle whenever the walking rhythm was lost or became unstable. Moreover, a safety pin was attached to the patients' collars, which had an attached sensor that immediately stopped the treadmill If the walker fell. As far as possible, the treadmill walking was performed comfortably without gripping the safety handle and the subjects were encouraged to walk as if it was their daily routine.

For the improvement of muscle activation and ankle-joint control of the lower limb, the exercise was performed by the experiment group that had Kinesio taping around the ankle joint and by the control group that wore the AFO for 30 minutes a day, three times a week, for a total of 4weeks.

2. 4. Statistical Analysis

For the statistical analysis of this study, the mean and standard deviation were computed using SPSS/window (version20.0). For the preliminary test of homogeneity of the dependent variable in each group, a t-test was performed. A paired t-test was performed to compare the within-group difference of the dependent variable before, and 4weeks after, the intervention. In order to examine the between-group difference of the change of the dependent variable before and after the intervention, an independent t-test was performed. The statistical significance level was set at $p < 0.05$.

3. Results

The muscle activity of the TA significantly increased in the experiment group after the experiment (p<0.05), while the control group did not show a significant difference (p> 0.05). Comparing between the groups, the experiment group showed a more significant increase compared to the control group (p<0.05). The muscle activity of the GCM significantly increased in both groups after the experiment (p<0.05). Comparing the two groups, the experiment group showed a more significant increase than the control group (p<0.05). The muscle activity of the GM was significantly increased in both the experiment group and the control group after the experiment (p<0.05). Comparing the two groups, the experiment group showed a greater increase than the control group, but there was no significant difference (p>0.05). The muscle activity of the RF significantly increased in both the experiment group and the control group after the experiment (p<0.05). Comparing the two groups, the experiment group showed a more significant increase than the control group (p<0.05) (Table 1).

Table 1. Mean (SD) of Groups, Mean (SD) difference within Groups, and Mean (95% CI) Differenceof Muscle Activity of between Groups

Outcome	Groups				Difference within groups		Difference between groups
Muscle activity during walking (uv)	Week 0		Week 4		Week 4 minus Week 0		Week 4 minus Week 0
	Exp (n=13)	Con (n=12)	Exp (n=13)	Con (n=12)	Exp	Con	Exp minus Con
Tibialis Ant	1055 (60)	1110 (622)	1192 (647)	1134 (611)	136 (73.9)	24 (50)	112 (59 to 165)
Gastrocnemius	985 (453)	1271 (604)	1145 (496)	1346 (690)	159 (99)	75 (117)	84 (30 to 123)
Gluteus Max	751 (212)	733 (199)	851 (250)	821 (228)	100 (69)	87 (87)	13 (6 to 20)
Rectus Femoris	1080 (358)	991 (330)	1473 (554)	1119 (372)	391 (442)	128 (88)	263 (135 to 402)

Exp = experimental group (taping during treadmill walking), Con = control group (AFO during treadmill walking)

The joint angle of dorsiflexion significantly increased in the experiment group from 7.58 to 11.17(p<0.05), while the control group did not show a significant difference with its joint angle changing from 7.68 to 8.61(p>0.05). Comparing the two groups, the experiment group showed a more significant increase than the control group (p<0.05). The joint angle of plantar flexion significantly increased in the experiment group from 5.11 to 8.14(p< 0.05), while the control group did not show a significant difference with its joint angle changing from 3.94 to 4.67(p<0.05). Comparing the two groups, the experiment group showed a more significant increase than the control group (p<0.05) (Table 2).

The gait velocity significantly increased in the experiment group from 34.44sec to 25.13sec, while the control group also showed a significant increase after the test from 30.89sec to 25.94sec (p<0.05). Comparing the two groups, the experiment group showed a more significant increase than the control group (p<0.05) (Table 2).

Table 2. Mean (SD) of Groups, Mean (SD) Difference within Groups, and Mean (95% CI) Difference of Ankle Joint Angle and Walking Speed of between Groups

Outcome	Groups				Difference within groups		Difference between groups
	Week 0		Week 4		Week 4 minus Week 0		Week 4 minus Week 0
	Exp (n=13)	Con (n=12)	Exp (n=13)	Con (n=12)	Exp	Con	Exp minus Con
DF at heel strike (deg)	7.6 (5.0)	7.7 (5.4)	11.2 (6.3)	8.6 (5.2)	3.6 (1.6)	0.9 (2.2)	2.7 (1.1 to 4.3)
PF at toe-off (deg)	5.1 (2.4)	3.9 (2.5)	8.1 (2.8)	4.7 (2.9)	3.0 (1.4)	0.7 (1.3)	2.3 (1.2 to 3.4)
10-m Walk Test (m/s)	0.32 (0.03)	0.34 (0.03)	0.48 (0.06)	0.41 (0.03)	0.16 (0.04)	0.07 (0.05)	0.05 (0.01 to 0.08)

Exp = experimental group (taping during treadmill walking), Con = control group (AFO during treadmill walking)

4. Discussion

The important functions of the ankle joint and feet of the body are to provide a driving force during walking, and shock absorption with the ankle joint, as well as controlling the balance upon posture disturbance, where the muscle strength of the ankle joint, the ROM, and the proprioceptive sense are required [31]. In particular, it is reported that TA and GCM are activated in the case of a small physical disturbance, while GCM is activated when the body moves forward. In a backward movement, TA is activated [32]. The foot drop symptom, due to rigidity and paralysis among the patients with stroke, shows characteristics of unstable feet and ankles as well as weakening muscles, which act as a critical disturbing factor for joint angle, walking, *etc.*, [33].

This study applied Kinesio taping on TA, GCM, and the ankle joint (figure-of-eight taping) of the patients with stroke that suffer foot drop symptoms. In order to minimize the overlap effects of the treadmill on walking improvement, treadmill velocity was set at the daily walking speed of the subjects according to their walking ability. The subjects performed the exercise for 30 minutes, three times a week for 4weeks (a total of 12 times). The control group performed the treadmill walking for the same period with an identical method while wearing the AFO walking aid. According to the experiment results, the experiment group that used Kinesio taping showed a more effective improvement in muscle activity of TA, GCM, RF, and GM, joint angle, and gait velocity, compared to the control group that used the AFO.

This study compared the change of TA and GCM muscle activity of both groups before and after the intervention. According to the comparison results, the experiment group showed a significant within-group difference ($p<0.001$) as well as significant between-group difference ($p< 0.05$), while the control group showed no significant change ($p>0.05$). It is conjectured that these results were caused by the fact that there was no muscular contraction of the muscle surrounding the ankle joint due to the fixed walking aid of the AFO in the control group. Similar to these study results, Kalsson and Andreasson [34] reported that applying taping on the ankle joint resulted in adequate control of the joint angle and a significant change of muscular contraction of the ankle stabilizing muscle. Han [35] reported significant muscle strength improvement of the ankle joint, the enhancement of ROM, and a proprioceptive sense improvement in the case of performing treadmill exercise after applying taping on the ankle joint. Moreover, Lee [36] reported a significant improvement in muscle strength and proprioceptive sense after applying Kinesio taping on the ankle joint. These are consistent with the previous study results, which argued that implementing exercise after applying taping can improve muscle strength during exercise, while reducing the shoulder joint pain of the patients with stroke [37].

This study compared the change of RF and GM muscle activity of both the experimental group and the control group before and after the intervention. According to the comparison results, both groups showed a significant within-group difference ($p<0.05$). Only RF turned out to have a significant difference between the experiment group and the control group ($p<0.05$). It is conjectured that ankle joint taping in a figure-of-eight shape played an effective role in supporting the ankle joint. The resulting stable ankle joint is surmised to have produced a significant change in RF and GM muscle activity of the paralyzed lower limb. Not only the Kinesio taping group, but also the AFO group showed muscle activity of the lower limb, which can be attributed to the stable supports for the ankle. However, the between-group change of GM did not show a significant difference ($p= 0.0658$). It is believed that a more detailed investigation on the muscle activity of GM in Kinesio taping and in AFO will be required in future studies.

This study compared the joint angle of the experiment group and the control group before and after the intervention. According to the comparison results, the experiment group showed significant within-group change ($p<0.001$) and a significant between-group difference was also observed ($p<0.05$). However, the control group did not show a significant change in either dorsiflexion or plantar flexion ($p>0.05$). In their experiment results, Callaghan et al. [38] reported an enhancement of ROM in the attached area after applying taping, which was consistent with the results in Ricard et al. [14] who reported ROM improvement after applying taping to the ankle joint. Moreover, Kang and Kim [39] showed a significant change in ROM after applying taping to patients with stroke for 12 times for 12 weeks.

While Kinesio taping, with its elastic properties, induces flexible movement of the joint angle during walking, the fixed-type walking aid of the AFO limits the joint angle. This could be the reason behind the absence of significant change after the intervention.

In this study, significant change was observed both in the experiment group and the control group after the intervention ($p<0.001$), along with a significant between-group change ($p<0.05$). Kim, *et al.,* [40] reported a significant change in 10MWT measurements after applying taping to the lower leg of the patients with stroke. Moreover, gait cycle duration improved through the ankle joint stabilization, which was consistent with the results in Jang [26], which examined the increase of muscle activity of quadriceps and gait velocity based on the stabilization of the ankle joint. This was also consistent with the previous study results, which reported an improvement of the gait cycle duration after AFO application [41].

This study also examined gait velocity, in addition to a significant difference in muscle activity and joint angle, which produced results similar to the previous studies. In contrast to the control group, the experiment group showed an improvement in gait velocity along with an improvement in muscle activity and the ROM of the ankle joint. It is conjectured that an actual improvement of gait ability took place rather than an improvement in asymmetric velocity using a compensation action. Patients with stroke show a drastic decrease of gait velocity as they have difficulty with selective muscle control due to the weakening muscle strength and rigidity of the affected side's lower limb. In contrast, an improvement in gait velocity is reported to be closely related to muscle strength recovery [42,43]. Through this taping of the ankle joints of stroke patients have shown a statistically significant effect than with the AFO. These results are thought to improve walking function of the limb and would be a good resource for future study.

We believe that further studies on the qualitative improvement with more detailed walking analysis regarding gait velocity enhancement after wearing the AFO will be required in the future. The group that used Kinesio taping (experiment group) showed a more significant change in muscle activity and gait velocity compared to the AFO-wearing group (control group). In particular, the Kinesio taping group showed an increase in the muscle activity of TA and GCM as well as a significant change of joint angle of dorsiflexion and plantar flexion, which were not observed in the AFO-wearing group. It is believed that the elasticity and ankle fixating, and the supporting role of Kinesio taping, caused a significant difference compared to the AFO walking aid.

There were a few limitations of this study: the sample size was not large since only the patients with stroke who had foot drop symptoms were selected as subjects, and the experiment proceeded using only some of the patients who satisfied the research criteria. Hence, it will be hard to generalize these study results to cover all the patients with stroke. Moreover, in the muscle activity evaluation, the muscle activity was measured simply with maximum muscle strength (MVIC), but muscle contraction timing, according to the gait cycle, was not analyzed. Hence, future studies are required to examine the intervention effects according to the muscle onset time, the maximum muscle contraction duration, and the muscle activity of each muscle by gait cycle. It was hard to control the Kinesio taping application time after the treadmill walking by the experiment group, while the control group also had individual variations in the AFO control time. Hence, further studies on the intervention effects of the application duration of Kinesio taping will be required in the future.

5. Conclusions

In this study, to evaluate Kinesio taping can improve muscle activity, joint angle, and gait ability in patients with stroke suffering foot drop. Experimental group participated in the Kinesio taping on ankle joint with treadmill walking, while control group wore AFO on ankle joint with treadmill walking for 4 weeks, 30 minutes per session, three times per week. Kinesio taping group showed a statistically significant improvement muscle activity, joint angle, and gait ability. We believe that the results of this study, where the significant effects of the AFO compared to the Kinesio taping on the ankle joint of the patients with stroke who suffered foot drop symptoms, were confirmed and can be useful for improving the walking function of those with foot drop, and for future studies on walking aids

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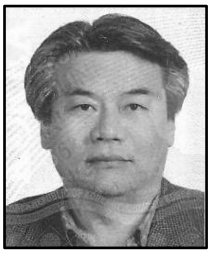

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