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Does correcting position and increasing sensorial input of the foot and ankle with Kinesio Taping improve balance in stroke patients?

Gokhan Yazici[a], Arzu Guclu-Gunduz[a,*], Deniz Bayraktar[b], Songul Aksoy[c], Bijen Nazliel[d], Muhammed Kilinc[e], Sibel Aksu Yildirim[e] and Ceyla Irkec[d]
[a]*Gazi University, Faculty of Health Sciences, Department of Physiotherapy and Rehabilitation, Ankara, Turkey*
[b]*Dokuz Eylul University, School of Physical Therapy and Rehabilitation, Izmir, Turkey*
[c]*Hacettepe University, Faculty of Health Sciences, Department of Audiology, Ankara, Turkey*
[d]*Gazi University, Faculty of Medicine, Department of Neurology, Ankara, Turkey*
[e]*Hacettepe University, Faculty of Health Sciences, Department of Physiotherapy and Rehabilitation, Ankara, Turkey*

Abstract.
BACKGROUND: We thought that the application of Kinesio Tape (KT) on the foot and ankle in stroke patients may improve the quality of somatosensory information and may activate ankle muscles which have an important role in postural control and that ultimately balance could be improved in stroke patients.
OBJECTIVE: The purpose of this study was to evaluate the effects of KT on balance in stroke patients.
METHODS: Nineteen stroke patients and 16 healthy controls were included in the study. The study group was evaluated with and without KT. Balance of the all subjects was evaluated Sensory Organization Tests (SOT) by using the Computerized Dynamic Posturography. Equilibrium, Strategy Analysis and Composite Equilibrium Scores were investigated in SOT.
RESULTS: Statistically significant differences were observed in all of the SOT parameters between stroke patients and healthy controls ($p < 0.05$). When the results with and without KT application were compared, the Equilibrium Scores in the conditions 3, 4, 6, Strategy Analysis Score in the conditions 2, 4, 6 and the Composite Equilibrium Score of the SOT were found to be improved in stroke patents ($p < 0.05$).
CONCLUSIONS: The results obtained from KT application are promising in improving balance in stroke patients.

Keywords: Stroke, Kinesio Taping, balance

1. Introduction

Stroke is a disease which causes disability in daily life, and reduces independence (Adamson et al., 2004). Balance disorders occurring after stroke are closely related to the degree of functional level (Tyson et al., 2007). Balance problems are shown as the most important reason of falling in chronic stroke patients (Lamb et al., 2003).

Balance is controlled by complex interactions of sensory and motor systems. Correct perception of stimuli from visual, somatosensory and vestibular systems in

*Address for correspondence: Assoc. Prof. Arzu Guclu-Gunduz, Gazi University, Faculty of Health Sciences, Department of Physiotherapy and Rehabilitation, Ankara, Turkey. Tel.: +90 312 216 26 29; Fax: +90 312 216 26 36; E-mail: arzuguclu@hotmail.com.

the central nervous system and correct regulation of these stimuli are necessary for good standing balance (Winstein et al., 1989; Shumway-Cook & Woollacott, 1995; Citaker et al., 2013). Disorders in the sensory system prevent the development of appropriate balance strategies (Manchester et al., 1989). Sensory disorders often seen in patients with stroke are shown to be one of the parameters responsible of disorders seen in walking and balance (Thurman et al., 2008). Oliveira et al. compared the balance of stroke patients and healthy subjects and the balance scores of stroke patients were found lower compared to healthy subjects. These researchers suggested that insufficient sensory information was responsible for poor balance in stroke patients (Oliveira et al., 2011). Based on this information and our clinical experience, we suggested that increasing the somatosensory information can improve the balance in stroke patients. On the other hand the most important issue at this point appears to be; how sensory inputs must be increased and in which body structure this increase should be performed. When we look at stroke rehabilitation with the Bobath Concept perspective, foot-ankle, trunk, head and neck are regarded as the key points of motor control (Holland & Lynch-Ellerington, 2009; Brock & Cotton, 2012).

When the literature is analyzed, the close relationship between sensorial input coming from the foot and ankle in neurological diseases and balance can be seen (Keenan et al., 1984; Niam et al., 1999; Citaker et al., 2011). Tyson and colleagues found that changes in foot and ankle proprioception, along with motor impairments, were the best predictors of balance abnormalities in stroke patients (Tyson et al., 2006). In our study, we regarded that the foot and ankle should not be just a simple support surface but must be considered as a key point of the motor control and balance. The foot and ankle work as an effective sensory organ in standing position and generate appropriate balance strategies (Van der Kooij et al., 2001). On the other hand because of the incorrect posture of the foot and thus lack of adequate contact with the ground, stroke patients cannot use the support surface of the foot effectively and appropriate sensory information cannot be received. This emerges as a major cause of poor balance in patients. In studies performed before to ensure proper posture of the foot, we can see techniques such as taping (Choi et al., 2013), use of orthosis (Fatone & Hansen, 2007) for the purpose of increasing contact with the ground. In our study, for these purposes we used the KT technique which allows the use of appropriate strategies of the foot due to its flexible property and also provides proper posture and improves kinesthetic senses. We thought that the application of KT on the foot and ankle in stroke patients may improve the quality of somatosensory information and may activate ankle muscles which have an important role in postural control.

KT can increase or inhibit muscle activation (Slupik et al., 2006) and increase the range of motion and joint stability (Yoshida & Kahanov, 2007). In literature, studies which use the KT in neurological disorders were limited (Kim et al., 2002; Karadag-Saygi et al., 2010; Cortesi et al., 2011; Choi et al., 2013). Kim et al., showed that KT applied on the ankle joint prior to exercise provides additional benefits on balance and gait in stroke patients (Kim et al., 2002). The investigators claimed that the gain acquired by the tape is associated with the tape preventing excessive movements of the ankle and providing somatosensory information.

Karadag-Saygi et al. have analyzed the effects of KT on the foot and ankle of patients with spastic equinus after botulinum toxin injection on spasticity, dorsiflexion range of motion, walking speed and step length. The researchers have found differences only dorsiflexion range of motion between the control group and KT group (Karadag-Saygi et al., 2010).

Cortesi et al. showed that the use of KT that was applied to calves brought about improvements in clinical and stabilometric measurements in patients with Multiple Sclerosis. They suggested that the use of ankle taping may be useful in immediately stabilizing body posture (Cortesi et al., 2011).

Choi et al. found that application of KT on the knee joint prior to proprioceptive neuromuscular facilitation method positively influences stroke patients' balance and gait (Choi et al., 2013).

Even though our clinical experience and limited literature, gives us information that KT can improve balance, it is seen that evidence is insufficient. Therefore in our study, we primarily wanted to examine the effects of KT on balance in stroke patients.

Our secondary goal was to compare the balance of stroke patients and healthy controls and observe in which parameters of the Sensory Organization Test the stroke patients were poorer. Our purpose was to see which balance strategy was affected the most in stroke patients and which body segment needs intervention. Thus we wanted to test our hypothesis concerning the increase of balance due to the sensory input provided by the application of KT on the foot and ankle.

2. Methods

2.1. Participants

Forty-one stroke patients and 16 healthy controls without any neurological problems were invited to the study. The stroke patients with functional ambulation level and level of disability were 0–3 according to Modified Rankin Scale (Banks & Marotta, 2007), post stroke duration of ≥1 month and whose spasticity of plantar flexor muscles were 0–2 according to Modified Ashworth Scale (Bohannon & Smith, 1987) were included the study. Subjects were excluded if they had plantar flexion contracture, cognitive impairment, previous surgery and botulinum toxin application of the plantar flexor muscles on the affected side, or allergy to taping. The study was approved by local ethics committee.

Balance assessments were done twice in individuals with stroke, one with KT and the other without KT. The individuals in the control group ($n = 16$) were evaluated only once without KT.

The probability of the patients learning The Computerized Dynamic Posturography tests in the first evaluation and achieving a better score in the second evaluation was considered and in order to prevent this, the stroke patients were divided into two groups by simple randomization method (Fig. 1). Thus, we wanted to see whether there was an impact of the learning effect on the test results. Balance of the first group (Group 1, $n = 9$) was evaluated firstly without the application of KT. After resting at the end of the first tests, the patients were taped using KT and reevaluated 30 minutes after application of KT. In the second group (Group 2, $n = 10$), initially, KT was applied and balance of the patients was evaluated 30 minutes after the application. When the initial evaluation was completed, the tape was removed and the patients were rested for 30–45 minutes. After resting the patients were evaluated again. Each evaluation lasted approximately 30 minutes.

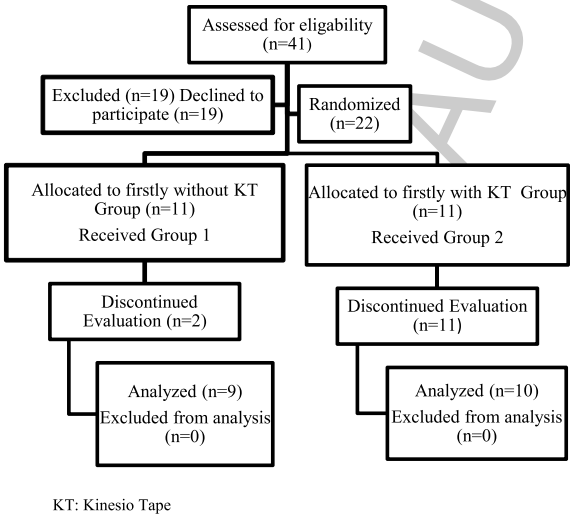

Fig. 1. Flowchart of the stroke patients throughout the trial.

2.2. Outcome measurements

Before the study, the patients' age, the duration of their disease, the ambulation levels in accordance with Modified Rankin Scale, the level of spasticity according to Modified Ashworth Scale and whether they use walking aids or foot-ankle orthosis have been recorded.

Balance Assessment: Balance was evaluated using The Computerized Dynamic Posturography (CDP) (NeuroCom International, Inc., Clackamas, SMART Balance Master). CDP is a method of assessing an individual's standing balance using different test conditions configured similarly with everyday life situations which can be encountered frequently (NeuroCom, 2007).

Sensory Organization Tests (SOT) was performed with the CDP. The SOT protocol objectively identifies abnormalities in the patient's use of the three sensory systems that contribute to postural control: somatosensory, visual and vestibular (NeuroCom, 2007). During the SOT, useful information delivered to the patient's eyes, feet and joints is effectively eliminated through calibrated "sway referencing" of the support surface and/or visual surround, which tilt to directly follow the patient's antero-posterior body sway. SOT was assessed at six different conditions. 1. condition; eyes open, fixed platform surface and background (in this situation, the subjects relies on visual, vestibular and somatosensory inputs); 2. condition; eyes closed, fixed platform surface and background (in this situation, the subjects uses mainly vestibular and somatosensory inputs to maintain balance because there is no visual information about his or her position in relation to the environment), 3. condition; eyes open, fixed platform surface and sway referenced visual background (in this situation, the subject should rely mainly on vestibular somatosensory information and not on visual inputs, which are not providing accurate information about his or her position in relation to the environment) 4. condition; eyes open and sway-referenced surface (in this situation, the subject uses mainly visual and vestibular inputs to maintain balance

because the somatosensory information is disorted), 5. condition; eyes closed and sway-referenced surface (in this situation, the subject uses mainly vestibular inputs to maintain balance because there is no visual information about his or her position in relation to the environment, and the somatosensory information is distorted and 6. condition; eyes open, sway-referenced surface and visual background (in this situation, the subject should use mainly vestibular inputs to maintain balance, because the somatosensory and visual information are distorted). Conditions 4, 5, 6 provide challenging sensory inputs, and conditions 3 and 6 introduce visual conflicts. The following parameters were evaluated at the SOT:

1. Equilibrium Score, quantifies the Center of Gravity (COG) sway, and measure postural stability under each of the three trials of the six SOT conditions. A score of 100 indicates no sway, whereas 0 indicates sway beyond the limits of stability.
2. Composite Equilibrium Score, the weighted average of the scores of all sensory conditions, characterizes the overall level of performance. Maximum score; 100.
3. Strategy Analysis quantifies the relative amount of movement about the ankles (ankle strategy) and about the hips (hip strategy) the patient used to maintain balance during each trial. Normal, stable individuals move primarily about the ankle joints when the surface is stable and shift to hip movements as they become less stable.

The patients were connected to the device during the tests with a vest and belt system in case of risk of falling.

2.3. Interventions

2.3.1. Taping

Taping was performed by a physiotherapist who is attended KT1, KT2 and KT3 Continuing Education Course and internationally certified. Subjects were taped in accordance to Kenzo Kase's Kinesio Taping Manual (Kase et al., 2003). Four different taping methods were performed (Fig. 2) for the purpose of: inhibition of gastrocnemius muscle, facilitation of dorsal flexors, the subtalar joint eversion for providing foot contact with the ground in the correct position and taping of the distal fibular head for correction of anterior tilt. The taping was applied with the ankle in neutral position in 4 steps. Patients were in prone position in the first step and supine position in the other 3 steps of taping. The first strip was for inhibition of the gastrocnemius muscle and began from the heel and attached to the medial and lateral heads of gastrocnemius muscle. The second strip was for the facilitation of the dorsiflexion muscles and began from the dorsum of the foot and was attached to the anterior aspect of the tibia using the paper-off technique. The third strip was for subtalar eversion and began from the medial malleolus, and was attached with maximum length of the tape, about 10 cm above the lateral malleolus from the sole of the foot. The last strip was for the correction of the distal fibular head and began from the anterior aspect of the ankle and was attached to the posterior aspect of the ankle with maximum length of the tape from the lateral side of the ankle.

2.4. Statistical analysis

All data were analyzed using the Statistical Package for the Social Sciences (SPSS1, Chicago, IL, USA, version 17). Data normality was tested using Shapiro-Wilk test. Demographic data were expressed as mean (±SD). Since were not normally distributed, comparisons were performed using Mann Whitney-U test or Wilcoxon signed-rank test and were expressed as median (IQR). Statistical significance was set at $p < 0.05$.

3. Results

Finally 19 patients (7 Female, 12 Male) and 16 healthy subjects (7 Female, 9 Male) were evaluated. Demographic and disease characteristics of the subjects were shown in Table 1. Spasticity of plantar flexor muscles was 1.94 ± 0.62 according to Modified Ashworth Scale.

Statistically significant differences were observed before taping in all of the SOT parameters between stroke patients and controls ($p < 0.05$, Table 2). We observed that SOT analysis scores of the patients are lower compared to healthy individuals and that the balance scores of stroke patients worsen as the information coming from the somatosensory, visual and vestibular systems decrease (Table 2).

When the results of balance analysis in stroke patients, with KT and without KT were compared, the Equilibrium Scores in the conditions 3, 4 and 6 and the Composite Equilibrium Scores of the SOT were found improved ($p < 0.05$, Table 3). In terms of Strategy Analysis Score, the improvements were observed in the conditions, 2, 4 and 6 states ($p < 0.05$, Table 3). These results showed us that, in cases of testing

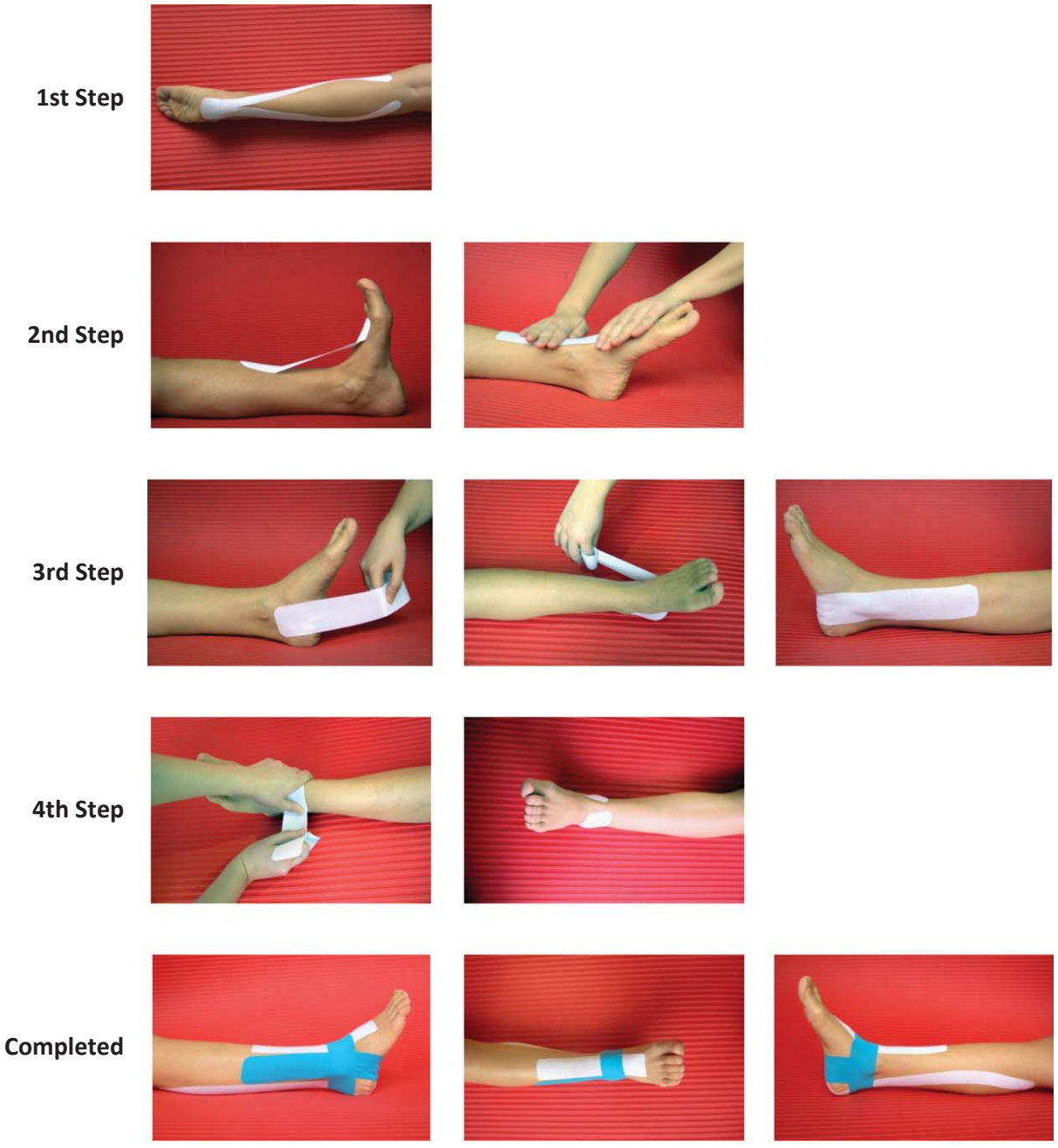

Fig. 2. Application of the Kinesio Tape.

where visual errors formed or sight is prevented and somatosensory inputs decreases, the somatosensory inputs can be increased through the KT application (Table 3).

No learning effect was observed in any of the evaluations, whether taping was applied firstly or lastly ($p > 0.05$, Table 4). This result supports the reliability of our findings on the effects of KT.

Table 1
Characteristics of subjects

	Experimental group $n = 19$	Control group $n = 16$	p
Age (year) (IQR)	53 (44/63)	52 (40.75–61.75)	0.728
Duration of disease, month mean ± SD	29 ± 21.14	–	
Modified Rankin Scale Score, (0–5) mean ± SD	2.05 ± 0.70	–	
Modified Rankin Scale Score, n (%)		–	
1	5 (%26)	–	
2	9 (%48)	–	
3	5 (%26)	–	
Walking aid use (%)	3(%16)	–	
Using Ankle Foot Orthosis (%)	4(%21)	–	

$p < 0.05$.

Table 2
Comparison of sensory organization test results in stroke patients and healthy control

Sensory organization test	Equilibrium scores			Strategy analysis scores		
	Experimental group $n = 19$ median (IQR)	Control group $n = 16$ median (IQR)	p	Experimental group $n = 19$ median (IQR)	Control group $n = 16$ median (IQR)	p
1. Eyes Open, Floor and Visual Environment Stable	91.5 (88.5/94.5)	94.25 (92.5/95.75)	0.025	94.5 (87.5/96)	96.75 (95.12/98)	0.008
2. Eyes Closed, Floor Stable	88.5 (85.5/92)	94 (90.87/95.87)	0.001	92.5 (88.5/95)	96 (94.5/97)	0.001
3. Eyes Closed, Floor Stable, Visual Environment Mobile	85.66 (81.66/89)	92.83 (91.08/94.32)	0.001	91 (83/93.33)	95.33 (94.25/96.24)	0.001
4. Eyes Open, Floor Mobile, Visual Environment Stable	74.33 (63/82.33)	85.66 (79.07/90.66)	0.001	84.33 (81/87.33)	90 (88/92.24)	0.001
5. Eyes Closed, Floor Mobile	62.33 (49/67.66)	68.33 (60.24/83.25)	0.031	72 (57/77.66)	82.16 (71.74/86.49)	0.016
6. Eyes Open, Floor and Visual Environment Mobile	53 (44.33/64.66)	71.33 (54.25/86.03)	0.031	65.33 (49.33/79.33)	83.33 (79.66/86.99)	0.001
The Composite Equilibrium Score	70 (62/77)	81 (73/88.75)	0.001			

$p < 0.05$.

Table 3
Comparison of sensory organization test results with and without Kinesio Tape in stroke patients

Sensory organization test	Equilibrium scores			Strategy analysis scores		
	Before KinesioTape $n = 19$ median (IQR)	After Kinesio Tape $n = 19$ median (IQR)	p	Before Kinesio Tape $n = 19$ median (IQR)	After Kinesio Tape $n = 19$ median (IQR)	p
1. Eyes Open, Floor and Visual Environment Stable	91.5 (88.5/94.5)	92.5 (89/94)	0.169	94.5 (87.5/96)	94 (90.5/96.5)	0.425
2. Eyes Closed, Floor Stable	88.5 (85.5/92)	90 (88/93)	0.070	92.5 (88.5/95)	94 (90/95)	0.008*
3. Eyes Closed, Floor Stable, Visual Environment Mobile	85.66 (81.66/89)	89 (84/92.33)	0.001*	91 (83/93.33)	91.33 (82.33/95.67)	0.546
4. Eyes Open, Floor Mobile, Visual Environment Stable	74.33 (63/82.33)	80.66 (73/85)	0.021*	84.33 (81/87.33)	86.67 (80.33/88.66)	0.035*
5. Eyes Closed, Floor Mobile	62.33 (49/67.66)	62.66 (52.67/67.33)	0.198	72 (57/77.66)	73.33 (65/79.66)	0.163
6. Eyes Open, Floor and Visual Environment Mobile	53 (44.33/64.66)	61.33 (54.33/68.66)	0.020*	65.33 (49.33/79.33)	72.3 (57.66/79.66)	0.042*
The Composite Equilibrium Score	70 (62/77)	75 (71/79)	0.001*			

*$p < 0.05$.

Table 4
Comparison of sensory organization test results for learning effect

Sensory organization test	Equilibrium scores			Strategy analysis scores		
	Group 1 $n=9$ median (IQR)	Group 2 $n=10$ median (IQR)	p	Group 1 $n=9$ median (IQR)	Group 2 $n=10$ median (IQR)	p
1. Eyes Open, Floor and Visual Environment Stable	0.5 (−1.4/1.25)	2 (−0.87/3.75)	−1.434	0 (−0.5/1)	0.75 (−2.88/2.38)	−0.412
2. Eyes Closed, Floor Stable	0.66 (−2.5/1.5)	1.5 (0.5/10)	−1.802	0.5 (−1/2.25)	1.5 (1/3.5)	−1.521
3. Eyes Closed, Floor Stable, Visual Environment Mobile	2.34 (0.01/5.5)	0.34 (0/2)	−0.041	0.66 (−0.84/4.84)	−0.5 (−2.25/6.08)	−0.858
4. Eyes Open, Floor Mobile, Visual Environment Stable	2.67 (−0.84/14.83)	7 (−2.12/10.41)	−0.041	1 (−0.5/3.33)	2.17 (−0.42/10.34)	−0.695
5. Eyes Closed, Floor Mobile	7.33 (−3.5/11.66)	9.34 (−9/11)	−0.082	6.66 (−1.67/12)	−0.17 (−4.09/7.92)	−1.184
6. Eyes Open, Floor and Visual Environment Mobile	8.33 (2.5/15.84)	2.16 (−5.09/11.83)	−1.348	11 (3.84/19.34)	−2.17 (−6.17/10.1)	−2.368
The Composite Equilibrium Score	4 (2/11)	3.5 (−0.5/8.5)	−0.861			

Group 1 was evaluated firstly without the application of KT, Group 2 was evaluated firstly with the application of KT, $p<0.05$.

4. Discussion

This study investigated the effects of KT on balance in stroke patients. It was found that improvements were found in the balance, while we could not achieve statistically significant results in all test conditions.

The results of the analysis of SOT showed that in situations where sensory inputs were reduced, stroke patients were not successful in maintaining balance when compared with healthy subjects. In the study conducted by Oliveira et al., the balance of stroke patients and healthy subjects was compared and in a similar manner to our study, the equilibrium scores of stroke patients were found lower compared to healthy subjects (Oliveira et al., 2011). SOT gives information about which strategy is used by subjects to maintain balance. In our study, when Strategy Analysis results were examined, the strategy score of stroke patients was found lower than that of healthy controls. This result is a sign that individuals use hip strategies more than the ankle strategy (NeuroCom, 2007) and suggests that patients use the ankle strategy less than controls. This result shows that, in order for patients to be able to use the ankle strategy in a better manner, we have displayed an accurate approach in interfering with the foot and ankles.

We investigated the effects of KT on balance when applied on the foot and ankle of patients with stroke. Following KT application, while we could not achieve statistically significant results in all test conditions, improvements were found in the equilibrium score, composite equilibrium score and strategy analysis of the SOT. This result shows that stroke patients show better adaptations with KT to visual illusions and ground movements when compared with no tape. The improvement observed in balance is thought to be associated with the KT ensuring the proper posture of the foot, and thus enhancing the contact of the foot with the ground and providing correct proprioceptive input. We also believe that foot contact with the ground in the correct position may have facilitated the activation of the ankle muscles. Our hypothesis was that; KT application will supply somatosensory inputs and when somatosensory inputs increase, the balance of stroke patients will improve. According to our results KT helped to increase somatosensory inputs and as a result of balance was found to be improved in stroke patients. On the other hand we think that KT should not be used solely, but with other neuro-rehabilitation methods. KT may help during balance and walking exercises. Because KT will not only contribute to foot posture but will also increase sensorial inputs.

When the literature is analyzed, it can be seen that there studies which analyze the effect of KT in stroke patients are not sufficient in number (Kim et al., 2002; Karadag-Saygi et al., 2010; Choi et al., 2013). Kim et al. examined the effects of KT on static balance, dynamic balance and gait in stroke patients (Kim et al., 2002). The researchers divided 23 stroke patients into 2 groups. In the first group ankle joint KT was performed alongside with classic physiotherapy treatment, in the second group only classic physiotherapy treatment was applied. After 8 weeks, improvements were seen in the balance and gait parameters in both groups but the

improvements were found to be significantly greater in the group which taping was applied. The researchers put forward that the gains they observed were associated with the tape preventing excessive movement in the ankle and providing somatosensory information. Karadag-Saygi et al. assessed the additive effect of KT on botulinum toxin injection in stroke patients with spastic equines (Karadag-Saygi et al., 2010). The researchers have applied KT in the foot and ankles of one of the groups they have separated into two after the botulinum toxin application ($n = 10$) and sham tape ($n = 10$) to the other. Both of the groups have received intensive rehabilitation for one month. As a result, the researchers have found out that, there is spasticity, passive dorsiflexion range of motion, gait velocity and step length developments in both groups. Although the development seems a bit more in the KT group, they have not observed a difference between the two groups. As a result, they have stated that the benefits of the KT application in stroke patients with spastic equines stroke is not clear and that further research on large number of patients is required. Choi et al. have researched the effects of KT application prior to the proprioceptive neuromuscular facilitation treatment in stroke patients on the hip and ankle joint angle, balance and walking speed (Choi et al., 2013). They were randomly assigned to either experimental group which received proprioceptive neuromuscular facilitation combination patterns and KT ($n = 15$), or a control group which received neurodevelopmental treatment for four weeks. Choi et al. have applied the KT application around the knee. As a result, while no development has been observed in the control group, they have observed significant development in the balance and walking speed of the experimental group. The researchers have claimed that through the KT application, there have been additional benefits as it increased the stability of the knee joint and muscle activity. Although KT has been applied to a different area from our study, KT was applied with the purpose of increasing stability and developments have been achieved. In the light of this study, it can be seen that there is a need for studies on where KT should be applied and through which technique it should be applied in patients with stroke.

In our study, we performed the taping on the foot and ankle because the foot is a support surface and an important organ in ensuring balance. However, the use of taping on different parts of the body, especially on the trunk, may contribute to balance. In our opinion, studies on the use of these applications as solely or as a combination are necessary.

5. Strength and limitations of the study

Throughout the study no negative side effect of KT was seen and none of the subjects reported any discomfort during the assessments.

When literature is examined, it can be seen that there is no consensus related to the technique, time, material and application area of KT (Kim et al., 2002; Karadag-Saygi et al., 2010; Cortesi et al., 2011; Choi et al., 2013). We believe that our study may provide base information for future studies.

The limitation of our study seems to be the fact that we only assessed the immediate effects of KT on balance in stroke patients and the small group of subjects. As a result we think that studies that examine the long term effects of KT are necessary with larger groups.

6. Conclusion

Balance in stroke patients was found to be defected when compared to healthy individuals. We concluded that KT applied on the foot and ankle in stroke patients, improves sensorial inputs but evidence is insufficient and studies in larger groups are needed to examine the long-term effects of KT.

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Conflict of interest

The authors declare that they have no conflicts of interest.

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