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Effects of Proprioception Training with Kinesio Taping of the Knee Joints on the Proprioception, Balance, and Gait in Stroke Patients: A Single-Blind Randomized Trials

Propriozeptives Training mit kinesiologischem Tape am Knie – Wirkung auf Propriozeption, Gleichgewicht und Gangbild bei Schlaganfallpatienten: Eine randomisierte Studie

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Authors
Jin Hong Kim[1], Kyung Hun Kim[2, 3 †], Dong Hoon Kim[2, 3 †]

Affiliations
1 Incheon Hospital, Korea Worker's Compensation & Welfare Service, Clinical Rehabilitation Research Center Incheon, KR
2 Gimcheon University, Department of physical therapy, 214, Daehak-ro Gimcheon-si, Gyeongsangbuk-do, Republic of Korea
3 Gimcheon Institute of Rehabilitation Science, Gimcheon University

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Correspondence
Prof, Kyung Hun Kim
Gimcheon University, Department of physical therapy
214, Daehak-ro Gimcheon-si
Gyeongsangbuk-do
Republic of Korea
huni040@naver.com
Tel.: 821071104690

Prof, Dong Hoon Kim
Gimcheon University, Department of physical therapy
214, Daehak-ro Gimcheon-si
Gyeongsangbuk-do
Republic of Korea
roopi00yo@naver.com
Tel.: 821029870490

ABSTRACT

The purpose of this study was to determine the effects of proprioception training with kinesio taping (PTKT) of the knee joints on the proprioception, balance and gait in Stroke Patients. The subjects were randomly divided into the PTKT group and control group, with subjects assigned to each group. In the PTKT group, proprioception training with kinesio taping was performed for 4 weeks. The control group was conducted in the same method except placebo kinesio taping. Proprioception error measure using the electrogoniometer. The balance ability was measure using the pressure plate. Gait ability was evaluated using G-Walk. The proprioception error, balance ability, and gait were significantly more improved in the PTKT group than in the control group ($p < 0.05$). These findings suggest that proprioception training with kinesio taping of the knee joints for proprioception, balance and gait in stroke patients.

ZUSAMMENFASSUNG

Ziel der Studie war es, die Wirkung von propriozeptivem Training mit kinesiologischem Tape (PTKT) am Knie auf die Propriozeption, das Gleichgewicht und das Gangbild bei Schlaganfall-

† These two authors contributed equally to this work as corresponding author

patienten zu prüfen. Die Patienten wurden randomisiert der PTKT-Gruppe oder der Kontrollgruppe zugeteilt. In der PTKT-Gruppe wurde ein propriozeptives Training mit kinesiologischem Tape über einen Zeitraum von 4 Wochen durchgeführt. In der Kontrollgruppe wurde in gleicher Weise vorgegangen, nur dass ein Schein-Tape-Verband verwendet wurde. Die Messung des Propriozeptionsfehlers erfolgte mittels eines Elektrogoniometers. Die Gleichgewichtsfähigkeit wurde mittels Druck- und Kraftmessplattform erfasst. Für die Prüfung der Gehfähigkeit wurde das Ganganalysesystem G-Walk verwendet. Die Verbesserung des Propriozeptionsfehlers, der Gleichgewichtsfähigkeit und des Gangbilds waren in der PTKT-Gruppe statistisch signifikant stärker ausgeprägt als in der Kontrollgruppe ($p < 0{,}05$). Die Ergebnisse legen nahe, dass propriozeptives Training mit kinesiologischem Tape am Knie sich positiv auf Propriozeption, Gleichgewicht und Gangbild bei Schlaganfallpatienten auswirkt.

Introduction

Strokes occur from the blockage of cerebral blood flow, and despite the recent significant advancements in the prevention and treatment of strokes, they continue to increase in incidence as circumstances unfold toward the unpredictable. When a stroke occurs, cells begin to die as oxygen supply to the brain cells is cut off, and the death of cells leads to the loss of the control portion of the brain region, such as cognitive ability and muscle control [1].

Most stroke patients experience problems with balance when sitting, standing, or walking [2], and patients with central nervous system injuries, including stroke patients, experience difficulties in performing activities of daily living due to a decrease in balance and mobility, exposing them to the constant possibility of secondary injury as a result of risks related to falling [3]. Stroke patients experience sensorimotor disturbances such as abnormal gait, lack of a proprioceptive sense, selective motor control impairment, and muscle weakness, with the possibility of a hemiplegic gait and an abnormal gait pattern, which occurs as a result of muscle weakness, weight-bearing and balance issues, accelerated deep tendon reflex, and co-contraction of synergy pattern muscles [4, 5].

The proprioceptive sense provides information on the angles and angular speed of all joints involved in body movement along with the proportions of the movement to the central nervous system, thus inducing normal movement and safely protecting the joints from injury [6]. However, stroke patients exhibit decreases in gait velocity and stride length due to the manifestation of abnormal joint position sense [7].

Among the various interventions for balance and gait in stroke patients, Kinesio taping (KT) is widely used as a regular method in rehabilitation programs [8]. Thin and highly elastic, KT reduces pain, improves joint position alignment, decreases swelling, increases proprioceptive sense, and increases or suppresses muscle recruitment [9]. Furthermore, it not only stimulates the proprioceptive sense without weight bearing at a comfortable position, but also increases postural control and gait ability by aligning joints at the correct position [10]. As a method capable of improving the functioning of stroke patients, KT training is used as an adjuvant therapy because of its positive effects on postural control, muscle strength improvement, mobility, and balance and gait patterns [11, 12].

Studies on changes in the balance and gait of stroke patients using KT continue to be conducted. These studies include a study that applied taping to the ankles of stroke patients with foot drop [13]. Rojhani-Shirazi et al. (2015) reported a significant increase in balance and gait ability by applying KT to the ankles of stroke patients for 24 hours [14], and Kim et al. (2012) reported a significant increase in static balance, dynamic balance, and gait after taping was applied to stroke patients for 8 weeks [15].

However, many of the preceding studies applied KT to the ankle joints, with none (to our knowledge) applying it to the knee joints. Moreover, very limited studies have examined the proprioceptive sense, postural control, and gait of stroke patients in combination with proprioception training of the knee joints. As a training method that improves the proprioception of stroke patients, proprioception training is mainly used as a variable for identifying the effects of new rehabilitation treatments [16]. Therefore, the present study attempts to provide reference data for designing interventions aimed at the proprioceptive sense, postural control, and gait of stroke patients by examining changes in proprioceptive sense, balance, and gait through the implementation of proprioception training with KT (PTKT) of the knee joints of stroke patients.

Materials and Methods

Subjects

The present study included 42 patients visiting K hospital in Gyeonggi-do, who met the inclusion criteria, which were as follows: 1) a stroke diagnosis, 2) without an allergic reaction to KT, 3) for whom 6 months had elapsed since the occurrence of stroke in order to minimize the possibility of spontaneous recovery, 4) medically stable, 5) without an occurrence of bilateral strokes or strokes on the contralateral cerebral hemisphere, 6) Korean mini-mental state examination (K-MMSE) 24 or higher [17], and 7) ability to communicate and understand and perform orders. All participants provided written consent, and the study was approved by the Institutional Review Board of Gimcheon University (GU-201805-HRa-02-P). The general characteristics of the subjects are presented in ▶ **Table 1**.

Sample Size Calculation

The basis for calculating the number of research subjects was based on statistical evaluation using G * power version 3.1.9.2 [18]. Preliminary research was conducted on 12 stroke patients in order to test the effect size of the subjects (six subjects for proprioception training with Kinesio taping and six subjects for proprioception training with placebo Kinesio taping). The effect size produced by the preliminary experiment through the mean error and standard deviation for the proprioceptive sense 12.33(1.97) and 10.67(1.21)

▶ **Table 1** General and clinical Characteristics of Subjects (N = 40).

Variable	PTKT group (n = 20)	Control group (n = 20)	p^b	p^c
Gender (Male/Female)	11/9	13/7	0.747	
Affected side (Left/Right)	12/8	9/11	0.527	
Diagnosis (Infarction/Hemorrhage)	7/13	1/9	0.340	
Height (*cm*)[a]	168.15 ± 6.93	165.98 ± 7.94		0.363
Age (*year*)[a]	53.70 ± 9.63	54.45 ± 7.28		0.783
Weight (*kg*)[a]	68.15 ± 8.75	67.52 ± 9.23		0.826
MMSE-K (*score*)[a]	26.65 ± 0.93	27.00 ± 0.97		0.253
Stroke duration (months)[a]	9.25 ± 1.89	9.60 ± 1.88		0.560

[a]Mean ± SD. [b]Chi-square test; [c]Independent t-test. MMSE, mini-mental state examination. PTKT group, kinesio taping with proprioception training group.

was 1.015428. Upon calculating the effect size, a significance level of 0.05, and a power of 0.80, it was estimated to be 34 subjects. Thus, the study was conducted with 40 subjects by assuming a dropout rate of 20 %.

Study Design

In this study, we used a pre-post control group design. Subjects were randomly assigned (randomization website: http://www.randomization.com) to a PTKT group and a proprioception training group that received placebo KT (control group). The present study applied a single-blind test, and three physical therapists with 5 years or more of clinical experience and a master's degree performed the intervention and measurements. Furthermore, the study was carried out without the subjects knowing which group they belonged to or any information about the intervention. All subjects were assessed for proprioception, balance ability, and gait ability before and 4 weeks after the intervention. The relevant intervention was administered to both groups for 30 min per day, five times per week, for 4 weeks.

Procedure

Proprioception training combined with the Kinesio taping

The PTKT group performed proprioception training combined with knee joint KT. KT (BB Tape, WETAPE Inc., Seoul, Republic of Korea) was used, and both I- and Y-shaped strips were used. The first tape was attached as an I-shaped strip from the knee ligament below the kneecap to the middle area of the rectus femoris muscle, with the tape stretched by 10–15 %. A Y-shaped strip was used as the second tape. With the KT stretched by 30 % and attached to the kneecap starting from below the knee ligament, one side of it is then attached to the middle area of the vastus lateralis muscle, while the remaining side is attached to the middle area of the vastus medialis muscle [19, 20] (▶ **Fig. 1**). Both groups were informed that they were receiving functional taping therapy. The taping was applied by a single physical therapist with 5 years or more of clinical experience and a master's degree. The subjects underwent proprioception training with tape attached to the knee joint. Proprioception training involved creating three lines in accordance with the angle of the knees with the heels together in a sitting position and then training the position of the legs, weight-shifting training from a sitting position to the paretic side, standing training from a sitting position, pelvic training with the knees bent in a standing position, a weight-bearing exercise for the kneecaps and ankle joints in a standing position, weight-shifting training toward various directions in a standing position, foot lifting training on the non-paretic side in a standing position, and task execution training of the upper limbs in a standing position [21, 22].

Control group

The control group underwent proprioception training combined with placebo KT of the knee joint. KT was applied horizontally to the kneecap and the middle area of the quadriceps femoris muscle (▶ **Fig. 1**). Apart from the location where the taping was attached, the control group performed training under the same conditions as those of the PTKT group.

Outcome Measurements

proprioceptive sense The present study used an electrogoniometer to test the proprioceptive sense. Proprioception involved specified angles (30°, 60°, 90°, 120°, 150°) and a 60 cm × 60 cm × 1 acrylic assessment board. With the subjects blindfolded and in an incorrect position, a random angle was chosen out of the five angles presented [23]. A therapist manually bent the knee to the initial target angle and then returned to the original position. The subjects were then made to position themselves to the angle they themselves bent to, and the difference in angle was measured using an electrogoniometer. The intra-rater reliability was high at $r = 0.86 \sim 0.87$ for the sitting straight position [24].

Balance ability Balance ability was measured using a pressure plate (FDM-SX, Zebris Medical GmbH, Germany) to identify balance in a standing position. First, the subjects comfortably placed their legs on the plate with their eyes open and then fixed their eyes on a dot 3 m in front of them while maintaining a standing position for 30 seconds [25]. Then, their sway area and path length were measured again for the shift in plantar pressure. Measurements taken with the eyes closed were conducted in the same position as when the eyes were open, with measurements taken after visibility was blocked using a blindfold. The intra-rater reliability of the measure-

ment equipment was 0.77~0.90 with the eyes open and 0.72~0.84 with the eyes closed [26].

Gait measurement equipment (G-Walk) The present study measured gait variables using a gait analysis system (G-Walk, BTS Bioengineering, Italy) to assess gait. The measurement variables included gait cadence, gait velocity, and stride length. The measurer carried out the tests after the subjects wore a belt on their waist for the measurement, and a pouch with a sensor was placed between the 5th lumbar vertebra (L5) and the 1st sacral vertebra (S1).

Data analysis SPSS software (SPSS Inc., Chicago, IL, USA, Ver. 21.0) was used to carry out the entire statistical analysis. Normality tests were performed by using the Shapiro-Wilk test. The independent t-test and the chi-square test for categorical variables were used to compare the general characteristics of subjects between the PTKT and control groups.

A two-way repeated measures analysis was conducted to determine the effects of the training. Time (within-subjects factors) refers to the outcome of the pre-post experiment training. Group-by-time (between-subjects factors) refers to the outcome of the experimental and control groups. If significant differences appeared in the analysis by group (interaction or main effect), a t-test was conducted. The significance level was set to $\alpha = 0.05$.

Results

Change of Proprioception error

Significant between-subject ($F = 137.643$, $p = 0.000$) and within-subject changes ($F = 22.550$, $p = 0.000$) were PE. PE showed sig-

▶ **Fig. 1** Kinesio taping technique; **a**: Knee joint kinesio taping method (PTKT group). **b**: Placebo taping method (Control group)

▶ **Table 2** Changes in proprioception error values between PTKT AND Control group.

Group/Measure	Pre-test	Post-test	Within-Subject Difference	Between-Subject Difference
PE (°)				
PTKT group (n = 20)	10.95 ± 1.57[1]	8.00 ± 1.49	−2.95 (−3.51, −2.39)[2]	−1.70 (−2.42, −0.98)[*,a,b]
Control group (n = 20)	11.3 ± 1.34	10.05 ± 1.15	−1.25 (−1.75, −0.75)[2]	

[1]Values are Mean ± SD. [*]$p < 0.05$, [2]subject Difference (time): significant improvement than per-test, [a]Between-subject Difference (time * interaction): Significantly greater improvement from the control group, [b]Analyed by two-way repeated measures ANOVA, PTKT group: kinesio taping with proprioception training group, PE: proprioception error angle.

▶ **Table 3** Changes in balance ability values between PTKT AND Control group.

Group/Measure	Pre-test	Post-test	Within-Subject Difference	Between-Subject Difference
EOSA (mm^2/mm)				
PTKT group (n = 20)	132.75 ± 44.57[1]	120.45 ± 42.58	− 12.30 (− 16.17, − 8.42)[2]	− 5.85 (− 10.23, − 1.47) [*,a,b]
Control group (n = 20)	133.45 ± 43.72	127.00 ± 42.02	− 6.45 (− 8.80, − 4.10)[2]	
EOPH (mm)				
PTKT group (n = 20)	155.75 ± 43.53	139.55 ± 47.25	− 16.20 (− 22.51, − 9.89)[2]	− 8.10 (− 14.80, − 1.40) [*,a,b]
Control group (n = 20)	161.75 ± 44.57	153.65 ± 44.51	− 8.10 (− 10.93, − 5.24)[2]	
ECSA (mm^2/mm)				
PTKT group (n = 20)	168.85 ± 36.40	154.00 ± 32.81	− 14.85 (− 19.48, − 10.22)[2]	− 7.98 (− 12.83, − 3.07) [*,a,b]
Control group (n = 20)	176.85 ± 36.60	169.95 ± 36.81	− 6.90 (− 8.91, − 4.89)[2]	
ECPH (mm)				
PTKT group (n = 20)	185.70 ± 36.95	170.95 ± 33.23	− 14.75 (− 20.13, − 9.37)[2]	− 6.75 (− 12.48, − 1.02) [*,a,b]
Control group (n = 20)	190.35 ± 38.23	182.35 ± 36.93	− 8.00 (− 10.48, − 5.52)[2]	

[1]Values are Mean ± SD. [*] $p < 0.05$, [2]subject Difference (time): significant improvement than per-test, [a]Between-subject Difference (time * interaction): Significantly greater improvement from the control group, [b]Analyed by two-way repeated measures ANOVA, PTKT group: kinesio taping with proprioception training group, EOSA: eye open sway area, EOPH: eye open path length, ECSA: eye close sway area, ECPH: eye close path length.

▶ **Table 4** Changes in gait ability values between PTKT AND Control group.

Group/Measure	Pre-test	Post-test	Within-Subject Difference	Between-Subject Difference
Cadence (steps/min)				
PTKT group (n = 20)	75.62 ± 8.45[1]	81.21 ± 9.46	5.59 (4.00,7.18)[2]	3.60 (0.71,6.49) [*,a,b]
Control group (n = 20)	78.53 ± 6.66	80.52 ± 6.49	1.99 (0.54,4.52)	
Gait velocity (m/sec)				
PTKT group (n = 20)	0.69 ± 0.05	0.74 ± 0.04	0.05 (0.03,0.06)[2]	0.03 (0.01,0.04) [*,a,b]
Control group (n = 20)	0.71 ± 0.04	0.73 ± 0.04	0.02 (0.02,0.02)[2]	
Stride length (cm)				
PTKT group (n = 20)	77.16 ± 7.01	82.36 ± 5.67	5.20 (3.66,6.75)[2]	3.89 (2.06,5.73) [*,a,b]
Control group (n = 20)	76.68 ± 7.13	80.99 ± 7.03	1.31 (0.21,2.41)	

[1]Values are Mean ± SD. [*] $p < 0.05$, [2]subject Difference (time): significant improvement than per-test, [a]Between-subject Difference (time * interaction): Significantly greater improvement from the control group, [b]Analyed by two-way repeated measures ANOVA, PTKT group: kinesio taping with proprioception training group.

nificantly more differences in the PTKT group than in the control group (▶ **Table 2**).

Change of balance ability

A significant between-participant changes were eye open sway area (EOSA) (F = 75.089, p = 0.000) and eye open path length (EOPH) (F = 53.926, p = 0.000). eye open sway area (EOSA) and eye open path length (EOPH) showed significantly more in the PTKT group than in the control group. Significant within- participant changes were EOSA (F = 7.309, p = 0.010) and EOPH score (F = 5.992, p = 0.019). A significant between-participant changes were: eye close sway area (ECSA) (F = 81.402, p = 0.000) and eye close path length (ECPH) (F = 64.616, p = 0.000). EOSA and EOPH showed significantly more in the PTKT group than in the control group. Significant within- participant changes were ECSA (F = 10.876, p = 0.002) and ECPH score (F = 5.688, p = 0.022) (▶ **Table 3**).

Change of gait ability

Significant between-subject change (F = 28.217, p = 0.000) and within-subject change (F = 6.365, p = 0.016) were cadence. Cadence showed significantly more differences in the PTKT group than in the control group. Significant between-subject change (F = 108.380, p = 0.000) and within-subject change (F = 17.989, p = 0.000) were gait velocity. Gait velocity showed significantly

more differences in the PTKT group than in the control group. Significant between-subject change (F = 51.626, p = 0.000) and within-subject change (F = 18.432, p = 0.000) were stride length. Stride length showed significantly more differences in the PTKT group than in the control group (▶ **Table 4**).

Discussion

Upon examining how the PTKT (20 subjects) and control groups (20 subjects) were impacted in terms of proprioceptive sense, balance, and gait, the study found that both groups experienced improvements within groups, and a comparison between groups found greater improvement in the PTKT group.

The most important training goals in terms of interventions for stroke patients are independent activity and gait. To achieve better gait function, balance in a standing position and postural balance control must be prioritized [27]. Furthermore, feedback from the outside is effective in the initial stage of motor learning for stroke patients, as this is extremely important for their rehabilitation [28].

Changes in proprioceptive sense in the present study demonstrated significant increases within both groups, and a comparison between groups revealed a significant increase in the PTKT group. After observing a correlation between the proprioceptive sense of the torso and balance in chronic stroke patients, Ryerson et al. (2008) claimed that the angle of error in terms of the proprioceptive sense of stroke patients was higher than that of normal people, and this was also correlated with balance [29]. Elis and Rosenbaum (2001) stated that patients with chronic ankle sprains underwent balance exercises on an unstable support surface, and experienced significant improvements in joint position sense over the control group [30]. Trans et al. (2009) stated that after patients with osteoarthritis in the knee joints underwent vibration training on a balance pad, they experienced statistically significant improvements in proprioceptive sense [31]. After investigating changes in proprioceptive function using KT combined with elastic bands, Hijmans et al. (2009) observed that KT significantly increased the proprioceptive sense of the knee joints [32]. Biomechanically, KT inflicts minute mechanical pressure on soft tissue, thereby extending it, and the resulting pressure and extension stimulate muscle spindles, the Ruffini (SA II) mechanoreceptors of the skin, and the type II and type III mechanoreceptors of the tendons, which can affect changes in proprioceptive response [33]. The present study also believes that a combination of KT and proprioception training of the knee joints is the cause of such an improvement in proprioceptive sense.

Changes in balance in the present study demonstrated significant increases within both groups, and a comparison between groups revealed a greater increase in the PTKT group. Delahunt et al. (2010) reported that applying ankle taping to subjects with ankle instability achieved significant improvements in postural stability [34], and Cakar et al. (2010) stated that taping, when applied to the lower limbs of stroke patients, can improve balance by providing stability, based on the concept of ankle joint orthosis [35]. Furthermore, Shin et al. (2014) claimed that taping applied to the kneecaps of chronic stroke patients achieved significant differences in balance variables [36]. Applying taping following the texture of the muscles that make the joints move improves the motor function of the muscles by expanding the space between the muscles and the skin and by increasing blood and lymph circulation [37]. Constant stimulation as a result of exercise makes the muscle spindles sensitive by way of gamma motor neurons, ultimately improving motor output by activating muscle fibers as the stimulation is transmitted to the alpha motor neurons, thereby having a positive impact on joint stability [38]. The improvement in motor function of the muscles as a result of such taping and joint stability resulting from proprioception training are considered to have a positive effect on improving balance.

Changes in gait in the present study demonstrated significant increases within both groups, and the comparison between groups revealed greater improvements in the PTKT group. Hyun et al. (2015) stated that applying taping to the knee joints of stroke patients achieved significant improvements in gait [39], and Nam et al. (2015) reported that taping applied to the lower limbs of stroke patients increased gait duration [40]. Alemdaroglu et al. (2013) reported that upon examining gait variables, they found that KT applied to the quadriceps femoris muscles of children achieved significant increases in step length [41]. As the core component of the sensorimotor system, proprioceptive sense provides afferent information used in neuromuscular control of the central nervous system and, at the same time, contributes to dynamic joint stability [42]. The KT and proprioception training of the knee joints in the present study are considered to improve gait by contributing to the activation of the sensorimotor system.

The limitations of the present study include the impossibility of excluding the impact of the subjects' daily lives on the dependent variables of the subjects due to the impossibility of completely controlling their daily lives. Furthermore, the results cannot be generalized and applied to the proprioceptive sense, balance, and gait of all stroke patients because the study was conducted with subjects who met the inclusion criteria. In the future, it will be necessary to carry out additional research that considers the diversification of applied KT and proprioception training methods as well as diversified proprioceptive sense, balance, and gait assessment tools.

Conclusion

The present study confirmed a positive effect of knee joint PTKT on the proprioceptive sense, balance, and gait of chronic stroke patients and ascertained the effectiveness of knee joint PTKT as part of rehabilitation training programs aimed at improving the proprioception, balance, and gait of chronic stroke patients in the future.

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Conflict of Interest

The authors declare that hey have no conflict of interest.

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