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Review Article

Effects of Taping on Balance and Gait in Patients With Stroke: A Meta-analysis

Eun-Ji Kim[1], PT, MSc, Joo-Hee Park[2], PT, PhD, Yixin Wang[1], PT, BPT, Hye-Seon Jeon[2], PT, PhD

[1]Department of Physical Therapy, The Graduate School, Yonsei University, [2]Department of Physical Therapy, College of Health Sciences, Yonsei University, Wonju, Korea

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Corresponding Author
Hye-Seon Jeon
E-mail: hyeseonj@yonsei.ac.kr
https://orcid.org/0000-0003-3986-2030

Key Words
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Background: Stroke is one of the causes affecting gait and balance. Taping is considered an effective method for improving balance and gait in stroke patients. Numerous studies have confirmed the functional effects of taping in stroke patients. However, there is still no consensus regarding the use of taping to improve gait and balance.

Objects: The purpose of this review was to investigate the effects of taping on the balance and gait of patients with stroke through meta-analysis of studies.

Methods: PubMed, Medline, Embase, Web of Science, Cochrane Review, RISS, DBPia, and Science on were used to collect articles on Kinesio and non-elastic taping. The key terms were "Stroke", "Hemiplegia", "Taping", "Tape", "Balance", and "Gait" with cut-off of October, 2022. Taping group was compared with control groups with sham, placebo, and no taping. The outcome measures included the Berg Balance Scale (BBS), Timed Up and Go (TUG) test, and gait speed (cm/s). Eighteen studies (524 patients) were selected for the meta-analysis.

Results: Overall, taping improved balance and gait in stroke patients, and Kinesio and non-elastic taping had similar effect sizes. Taping improved the BBS and TUG, and was most effective on gait speed. Contrary to the expectation that a longer duration of taping would be more affective, taping was most effective when the total taping duration was shorter than 500 minutes. In addition, the effect size of taping was greater when it was simultaneously attached to multiple locations.

Conclusion: This meta-analysis supports the use of taping to improve gait and balance in stroke patients, and provides guidelines for the location, duration, and type of tape to increase taping efficiency.

INTRODUCTION

Taping has been used to improve balance and gait in patients with stroke [1-3]. In general, taping enhances the delivery of sensory input by facilitating the connection between the skin and proprioceptive receptors, improves joint alignment and stability, and facilitates the activity of lower limb muscles such as the tibialis anterior, quadriceps, and gluteus maximus [4-10] and also shows efficiency in terms of time and space utilization at a low cost [11]. Kinesio (elastic) and non-elastic tape are most frequently used in patients with stroke. Kinesio tape was developed by Kenzo Kase to provide skin-like elasticity with 120%–140% tension [4]. Non-elastic tape is mainly used to support the area where it is applied [12]. According to various studies, taping has been used to stimulate proprioception in patients with stroke, provide stability to joint movement, and increase muscle activity [13-15]. Previous studies, have confirmed that taping has a positive effect on gait and balance in patients with stroke. However, there is still no standard for taping application.

Although several previous systematic reviews have reported positive effects of Kinesio taping on gait and balance ability in patients with stroke [16-18], no meta-analysis study has examined the effectiveness of both Kinesio as well as non-elastic taping in patients with stroke. Furthermore, the attachment site, method, and duration of taping were not discussed in previous studies. Therefore, in this study, a meta-analysis of randomized controlled trials was conducted to investigate the effects of Kinesio and non-elastic taping on the balance and gait of patients with stroke.

MATERIALS AND METHODS

1. Search Strategy

Published research works as of October 2022 were retrieved through eight electronic databases (PubMed, Medline, Embase, Web of science, Cochrane Review, RISS, DBPia, Science on). The key terms were "Stroke", "Hemiplegia", "Taping", "Tape", "Balance", and "Gait". After selecting the title and abstract of the thesis, the full text was reviewed according to the study selection criteria. Two reviewers, EJK and YW (Master's degree and BHS researcher respectively), independently searched and selected the relevant articles. Any differences between the reviewers, were resolved through a meeting. The reference lists of previous systemic reviews and retrieved articles regarding insoles were also manually examined to search for additional articles.

2. Eligible Criteria

All experimental studies that met the following criteria were included: (1) Involving patients diagnosed with stroke for more than 3 months; (2) Kinesio taping and non-elastic taping on the affected side only; (3) randomised controlled trial (RCT) study; (4) pre-post design with a control group (sham, placebo, and non-taping); (5) using Berg Balance Scale (BBS), Timed Up and Go (TUG), and gait speed for measurement; and (6) written in English and Korean. Case studies, cross-over studies, review articles, books, and inaccessible full texts were excluded. Literature that did not specify taping application duration for each session or applied additional interventions other than conventional therapy and treadmill gait training were also excluded from this study.

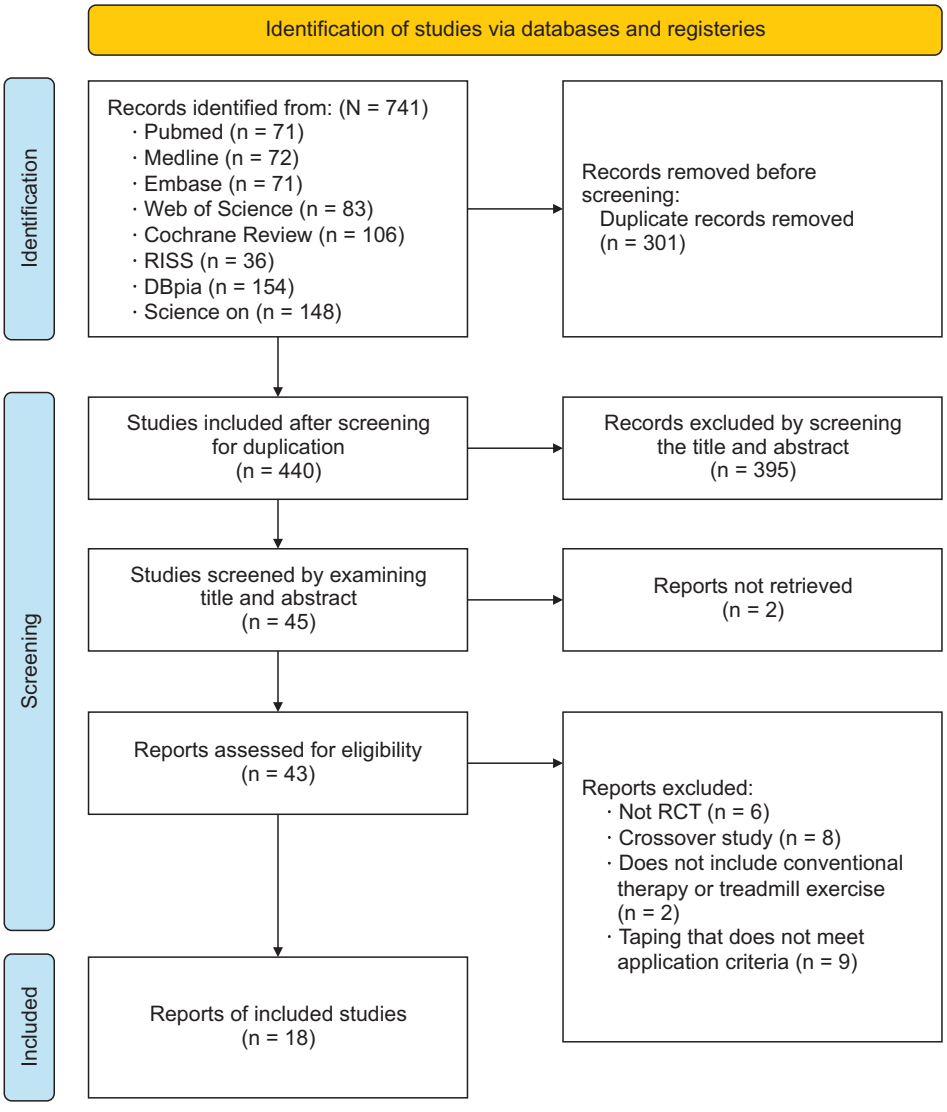

Figure 1. Flow chart of the study.

3. Study Selection

Initially, 741 studies were searched in eight electronic databases. A total of 301 overlapping studies were excluded, leaving 45 studies after screening the titles and abstracts. After searching and reviewing full-text articles, 27 studies were excluded. Therefore, 18 studies were ultimately included in this meta-analysis (Figure 1).

4. Study Quality

Study quality was assessed using the PEDro scale, which is valid and reliable for assessing the quality of RCTs [19,20]. Two independent assessors (EJK and YW) obtained scores for each trial from the PEDro database. The total score ranges from 0 to 10, with scores of 9–10 (excellent), 6–8 (good), 4–5 (fair), and 0–3 (poor).

5. Data Collection Process

Five features reflecting the variables were coded: (a) taping type, (b) outcome, (c) total taping duration, (d) taping site, and (e) taping target (Table 1).

(a) 'Taping type' represents the type of taping used in the primary studies. Primary studies used two types of taping: Kinesio taping and non-elastic taping. Kinesio taping is applied using a tape with elastic tension. Non-elastic taping is the application of a tape with no tension.

(b) 'Outcome' were BBS, TUG, and gait speed. The BBS was used to assess static and dynamic balance; TUG to assess balance, walking speed, and functional movement; and gait speed to determine walking distance in cm per second.

(c) 'Total taping duration' represents the total time that the tape was attached to the body part throughout the intervention. For example, if tape was applied for 60 minutes per session for 5 days, the total taping application time was 300 minutes. 'Total taping duration' was divided into four categories as 'immediate', 'less than 500 minutes', 'less than 1,000 minutes', and 'more than 1,000 minutes'. In general, taping is applied three times a week for 30 minutes per session in clinical practice [21,22]. The frequencies and durations of taping in the studies included in this meta-analysis varied significantly. The criterion for grouping the total application time was arbitrarily selected in this meta-analysis; most of the 'less than 500 minutes' studies lasted 4 weeks, 'less than 1,000 minutes' lasted 6 weeks, and 'more than 1,000 minutes' lasted longer than 6 weeks. Studies conducted in one session to confirm the immediate effect on the same day were coded as 'immediate'.

(d) 'Taping site' indicates the location where the taping is applied and were coded by 'ankle', 'knee', 'hip', 'trunk', and 'ankle and knee'; when taping was applied to both the ankle and knee, it was coded as 'ankle and knee'.

(e) 'Taping target' was coded according to the purpose of the taping, which is 'muscle', 'joint', and 'muscle and joint'. When attached to a muscle, it was coded as a 'muscle'. Joint taping is a direct taping attachment to a joint that provides stability. Muscle and joint taping was defined as taping applied to both the joint and muscle, simultaneously.

6. Calculating Effect Size

The comprehensive Meta-Analysis Software ver. 3 (Biostat) was used in this study. The effect size is presented as the standardized mean difference (Cohen's d). To determine the outcome analysis model, the heterogeneity of the sampling used in the selected studies was confirmed using Q and I^2 values. The Q value in this study was 19.376 (df = 17, p = 0.307), and the I^2 value was 12.261%. Therefore, a fixed-effects model was used to estimate the overall effect because the I^2 value was less than 50% [23].

Additionally, subgroup analyses were conducted using the following categorical moderators: taping-type outcome, total taping duration, taping site, and taping target. In general, each primary study in a meta-analysis should be independent; however, using various effect sizes from one study can violate this assumption. However, Cooper's "shifting units of analysis" insist that effect sizes can be a unit of analysis when a subgroup analysis is conducted, and this process helps prevent loss of beneficial information. Thus, we decided to use the effect size as a unit of analysis when conducting moderators, taping-type outcomes, total taping durations, taping sites, and taping targets.

RESULTS

Eighteen studies [24-41] with 524 participants were included in this meta-analysis. An RCT by Gill [39] that compared the treatment effects among Kinesio taping, non-elastic taping, and treadmill groups included two separate studies: Kinesio taping vs. conventional therapy and non-elastic taping vs.

Table 1. Overview of study characteristics of the meta-analysis

Study	Year	Experimental group	Control group	Taping type	Taping site	Taping target	Outcome	Duration/total treatment session/ total taping duration	PEDro scale
Lee [24]	2022	Taping + conventional therapy	Conventional therapy	Kinesio tape	Ankle and knee	Muscle and joint	TUG, BBS, Gait speed	Immediate/1/30 min	6
Seo Mun [25]	2017	Taping + treadmill	Treadmill	Kinesio tape	Ankle and knee	Joint	TUG, Gait speed	Immediate/1/30 min	6
Kim et al. [26]	2012	Taping + conventional therapy	Conventional therapy	Kinesio tape	Ankle	Muscle and joint	TUG	8 weeks/24/720 min	6
Sheng et al .[27]	2019	Taping	None	Kinesio tape	Ankle	Joint	TUG	Immediate/1/none	6
Rojhani-Shirazi et al. [28]	2015	Taping	None	Kinesio tape	Ankle	Joint	TUG, BBS	1 day/1/1,440 min	5
Park et al. [29]	2020	Taping + treadmill	Treadmill	Non-elastic tape	Ankle	Joint	Gait speed	Immediate/1/10 min	7
Lee et al. [30]	2012	Taping + conventional therapy + treadmill	Conventional therapy + treadmill	Non-elastic tape	Ankle	Joint	TUG	2 weeks/10/2,400 min	6
Kim et al. [31]	2021	Taping + treadmill	Sham taping + treadmill	Kinesio tape	Ankle	Muscle	Gait speed	4 weeks/20/600 min	8
Wang et al. [32]	2022	Taping + conventional therapy + treadmill	Sham taping + conventional therapy + treadmill	Non-elastic tape	Hip	Muscle	BBS	6 weeks/12/600 min	6
Nam et al. [33]	2015	Taping + conventional therapy + treadmill	Conventional therapy + treadmill	Non-elastic tape	Knee	Muscle	TUG, BBS	6 weeks/18/540 min	6
Seo et al. [34]	2020	Taping + treadmill	Treadmill	Kinesio tape	Trunk	Muscle	TUG, BBS	6 weeks/18/540 min	6
Hyun et al. [35]	2015	Taping	Placebo taping	Non-elastic tape	Knee	Joint	Gait speed	Immediate/1/none	5
Gill et al. [36]	2022	Taping + treadmill	Treadmill	Kinesio tape	Ankle	Muscle	TUG	4 weeks/12/480 min	6
Jeong et al. [37]	2016	Taping + treadmill	Treadmill	Kinesio tape	Ankle	Muscle	TUG	6 weeks/30/1,500 min	6
Shin and Chung [38]	2015	Taping + treadmill	Treadmill	Non-elastic tape	Knee	Joint	Gait speed	4 weeks/20/600 min	5
Gill [39]	2022	Taping + treadmill	Treadmill	Kinesio tape	Ankle	Muscle	TUG	4 weeks/12/480 min	6
Gill [39]	2022	Taping + treadmill	Treadmill	Non-elastic tape	Ankle	Muscle	TUG	4 weeks/12/480 min	6
Kim and Knag [40]	2018	Taping + treadmill	Treadmill	Kinesio tape	Ankle	Muscle	TUG	6 weeks/30/1,500 min	6
Lee and Cho [41]	2018	Taping	Sham taping	Kinesio tape	Hip	Muscle	TUG	Immediate/1/none	7

TUG, Timed Up and Go; BBS, Berg Balance Scale.

treadmill. Therefore, Gill [39]'s study was counted as two studies in this meta-analysis.

1. Publication Bias

No publication bias was found in this meta-analysis. Begg and Mazumdar's rank test yielded a p-value of 0.59591, and Egger's regression intercept yielded a p-value of 0.95443, indicating no evidence of publication bias. The funnel plot, confirmed that it was visually symmetrical (Figure 2).

2. Study Quality

The average PEDro scale score of all 18 studies was 6.05 out of 10, range 5 to 7. This can be interpreted as having "fair" and "good" quality [20]. The detailed information is shown in Table 1.

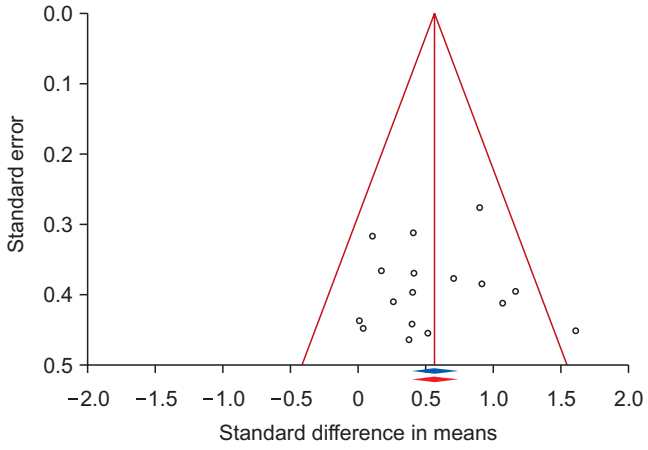

Figure 2. Funnel plot of standard error by standard difference in means.

3. Overall Effect Size of Taping

The overall effect size of taping was 0.567 in the random effect model (Q = 19.376; p = 0.307; I^2 = 12.261). According to Cohen's definition, taping had a medium effect on patients with stroke (small effect, ≥ 0.20; medium effect, ≥ 0.50; large effect, ≥ 0.80).

4. Subgroup Analysis

A total of 19 effects among 18 studies were categorized into the following moderators to conduct subgroup analysis: (1) taping type (2) outcome, (3) total taping duration, (4) taping site, and (5) taping target. Analyses of the mean change differences were calculated using a fixed-effect model (Table 2).

1) Subgroup analysis for taping type

Because Gill [39]'s study was counted as two separate studies, a total of 12 studies applied Kinesio taping [24-28,31,34,36,37,39-41], and seven studies applied non-elastic taping [29,30,32,33,35,38,39]. The effect size of Kinesio taping (0.555) was similar to that of non-elastic taping (0.484).

Table 2. Effect sizes by meta-analysis

Subgroup	N	Effected size	95% confidence interval	Standard error
Total	19	0.567	0.391–0.743	0.090
Taping type				
Kinesio tape	12	0.555	0.338–0.750	0.105
Non-elastic tape	7	0.484	0.174–0.820	0.165
Outcome				
Berg Balance Scale	5	0.410	0.072–0.747	0.172
Timed Up and Go	14	0.457	0.250–0.664	0.106
Gait speed	6	0.925	0.615–1.235	0.158
Total taping duration				
Immediate	6	0.741	0.426–1.056	0.161
Less than 500 min	3	0.590	0.151–1.029	0.224
Less than 1,000 min	6	0.391	0.084–0.697	0.156
More than 1,000 min	4	0.402	0.033–0.771	0.188
Taping site				
Ankle	11	0.535	0.313–0.757	0.113
Knee	3	0.565	0.135–1.178	0.266
Ankle and knee	2	0.999	0.440–1.559	0.285
Hip	2	0.144	−0.216–0.696	0.233
Trunk	1	0.024	−0.853–0.900	0.447
Taping target				
Muscle	10	0.360	0.106–0.614	0.130
Joint	7	0.610	0.351–0.870	0.133
Muscle and joint	2	1.021	0.440–1.602	0.296

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2) Subgroup analysis for outcome

The effect size of the five studies that measured BBS was 0.410 [24,28,32-34], and that of 14 studies that measured TUG [24-28,30,33,34,36,37,39-41] was 0.433. The effect size of the six studies that measured gait speed [24,25,29,31,35,38] was 0.925. It can be interpreted that taping has the greatest effect on gait speed, and a small-to-medium effect on BBS and TUG.

3) Subgroup analysis for total taping duration

According to the total taping duration, effect size of six studies classified as immediate [24,25,27,29,35,41] was 0.741, effect size of three studies classified as less than 500 minutes [36,39] was 0.590, effect size of six studies classified as less than 1,000 minutes [26,31-34,38] was 0.391, effect size of four studies classified as more than 1,000 minutes was 0.402 [28,30,37,40]. 'Immediate' and 'less than 500 minutes' showed a medium effect size, and 'less' and 'more than 1,000 minutes' showed a small effect model. Among these, the effect size of 'immediate' was the largest.

4) Subgroup analysis for taping site

Eleven studies were classified as ankle (taping site) [26-31,36,37,39,40] with an effect size of 0.535. Three studies were classified as knee [33,35,38] with an effect size of 0.565. Two studies were classified as ankle and knee [24,25], with an effect size of 0.999. When taping was applied to both joints, it can be interpreted as more effective compared to applied only to either ankle or knee.

Two studies were classified as hip [32,41] and had an effect size of 0.144. One study was classified as trunk [34] and had an effect size of 0.024. It can be interpreted that both taping methods have a small effect on gait speed and balance.

5) Subgroup analysis for taping target

Ten studies were classified as muscle [31-34,36,37,39-41] with an effect size of 0.361. Seven studies were classified as joint [25,27-30,35,38] and had an effect size of 0.610. This can be interpreted as meaning that taping of joints is more effective than muscle taping.

Two studies were classified as muscle and joint taping [24,26] with an effect size of 1.021. This can be interpreted as a method that combines the two taping methods to make it more effective.

DISCUSSION

Several studies have been conducted to confirm the effectiveness of various rehabilitation interventions for functional recovery in patients with stroke. Compared to rigid orthoses, taping is advantageous in providing some degree of joint mobility and stability with minimal restriction of joint movement [42,43]. However, previous reviews that examined the effects of taping on balance and gait function in people with stroke reported inconsistent effect sizes depending on the type, method of taping, application location, and application time. Therefore, this meta-analysis was conducted to identify the overall effects of taping to improve gait and balance function in stroke and examine how the effectiveness of taping varied by type, location, application method, and duration of intervention.

First, taping was moderately effective in improving balance and gait function after stroke. Although the effect size of Kinesio taping was slightly greater than that of non-elastic taping, the difference was not significant. This finding is consistent with the results of previous studies. Both types of taping were effective in improving gait and balance in patients with stroke; however, there was no significant difference between the Kinesio taping and non-elastic taping groups [44,45]. Kinesio taping is known to be beneficial for the timing of muscle activation and joint control during gait by facilitating muscle activity [46,47], and promoting or inhibiting muscle tone at the application site [48]. By contrast, non-elastic taping provides stability [49], and corrects joint alignment by limiting unnecessary joint motion through rigid tape characteristics [50]. Owing to these positive characteristics, there was no significant difference in the effect sizes of the two types of tapes.

The results of separate meta-analyses on each outcome revealed that effect size had the greatest effect on gait speed, followed by TUG and BBS. This finding is not consistent with the results of a previous meta-analysis to identify the effect of ankle Kinesio taping on balance and gait-related outcomes for stroke [18]. They reported a greater effect on balance than gait in the study, and this inconsistency between the previous and present studies is mainly thought to be because our analysis included studies that applied taping to body parts other than the ankle, as well as those that applied non-elastic taping. In addition, a study by Kim et al. [1] suggested that there was no significant difference in BBS when taping was applied. Therefore, it can be inferred that BBS had a relatively low effect size

in this meta-analysis.

Contrary to general expectations, it could not be confirmed the difference in the taping effect increased with application time, compared with conventional rehabilitation treatment. More interestingly, the effect size was greatest when the meta-analysis was conducted separately with cross-sectional studies that examined the immediate effect of taping in stroke. Subgroup effect size was observed to be below 500 minutes, and no large effect size was shown above or below 1,000 minutes. This is consistent with a previous meta-analysis showing that an intervention of more than 4 weeks was more effective on balance and walking ability than an intervention of 6 weeks when Kinesio taping was applied [51]. When applying taping to patients with in addition to conventional therapy or treadmill exercise, taping shows a rapid effect at the beginning of taping intervention, but as the treatment period lengthens, the relative treatment effect does not differ significantly from that of conventional therapy alone. Increased stability and movement control in the paretic limb could be related to this kind of instant and relatively rapid improvement in gait. Therefore, applying taping with exercise over a certain period of time as well as immediate taping will be effective for patients' gait and balance.

With regard to taping location, our study revealed that taping was the most effective when applied simultaneously to both the ankle and knee. The taping method attached to the ankle and knee alone showed a medium effect size, whereas the taping method attached to the hip and trunk showed a small effect size on balance and gait. These results are consistent with the findings of previous studies that applying Kinesio taping only to the ankles of patients with stroke is relatively ineffective [18]. Gait impairment in patients with stroke is related to stiffness and weakness of the ankle and knee [52-54]. Normal gait control is achieved by coordinated inter-segmental control of the ankle, knee, head, and arm [55].

According to our findings, taping is most effective when applied to both the muscle and joint, and was least effective when applied to the muscle only. This is consistent with previous studies showing that when taping was applied separately to the muscle and joint of patients with stroke, joint taping had a greater effect on balance and gait [2]. Physiologically, muscle taping induces muscle relaxation and increases muscle strength through enhanced Golgi tendon organ and muscle spindle activity [56], and facilitates muscle activity [57]. On the other hand, taping primarily provides mechanical stability to the paretic limb joints [58,59]. It also augments proprioception of the involved joint and ultimately improves the paretic limb mobility [60,61]. Because movement impairment in the paretic side is the consequence of interrelated failure in both muscles and joints, taping is suggested to be applied to the joints and muscles simultaneously in order to maximize its effect of taping on patients with stroke.

This study provides the latest evidence for the effect of taping on balance and walking in patients with stroke. The findings of this meta-analysis indicate that there are many factors to be considered when applying taping to improve balance and gait in stroke, such as the type, location, and duration of taping. This study had several limitations. First, this study included experimental research that used BBS, TUG, and gait speed as outcome measures of balance and gait function. Therefore, future meta-analyses that include additional experimental studies measuring dynamic gait function are necessary to provide more meaningful evidence to support the use of taping in patients with stroke. Second, the number of original papers belonging to each category of a specific independent variable was insufficient to derive meaningful and reliable results. Therefore, additional well-constructed RCTs should be conducted for high-quality meta-analyses.

CONCLUSIONS

In this study, a meta-analysis was conducted to verify the effect size according to the application method of taping, which is mainly used in patients with stroke. Eighteen studies were analyzed, and the overall effect size was calculated to be 0.567, which showed a medium effect size. In particular, both Kinesio taping and non-elastic taping showed medium effect sizes, and it was confirmed that there was no significant difference in effect size. This can be said to be effective for improving gait and balance, regardless of the type of taping applied to patients with stroke.

Taping showed the largest effect size when the ankle and knee were attached in a manner that could stimulate the muscles and joints, simultaneously. This shows that attaching taping to multiple joints rather than to single joints can provide stability, and that taping that provides both stability and muscle activity can be more effective for gait and balance. In addition, taping showed the largest effect size in immediate

results and gait speed. This shows that it can be effective as an intervention to improve the gait speed, especially in a relatively short-term application. Therefore, selecting the taping type, method, and time suitable for this purpose can contribute to a more efficient gait and balance improvement in patients with stroke.

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CONFLICTS OF INTEREST

No potential conflicts of interest relevant to this article are reported.

AUTHOR CONTRIBUTION

Conceptualization: EJK, HSJ. Data curation: EJK, YW. Formal analysis: EJK, JHP, YW, HSJ. Investigation: EJK, JHP, YW, HSJ. Methodology: EJK, JHP, YW, HSJ. Project administration: EJK, JHP, HSJ. Resources: EJK, JHP, YW, HSJ. Supervision: EJK, HSJ. Validation: EJK, JHP, HSJ. Visualization: EJK, JHP, HSJ. Writing - original draft: EJK, JHP. Writing - review & editing: EJK, HSJ.

ORCID

Eun-Ji Kim, https://orcid.org/0000-0002-8108-5901
Joo-Hee Park, https://orcid.org/0000-0001-9545-1362
Yixin Wang, https://orcid.org/0000-0001-7280-986X

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