Complementary Therapies in Clinical Practice 35 (2019) 22–32

Contents lists available at ScienceDirect

Complementary Therapies in Clinical Practice

journal homepage: www.elsevier.com/locate/ctcp

Use of Kinesio taping in lower-extremity rehabilitation of post-stroke patients: A systematic review and meta-analysis

Mian Wang[a,b], Zi-wen Pei[c], Bei-dou Xiong[d], Xian-mei Meng[a], Xiao-li Chen[a,*], Wei-jing Liao[e]

[a] School of Health Sciences, Wuhan University, Wuhan, Hubei, China
[b] Infrastructure Management Department, Renmin Hospital of Wuhan University, Wuhan, Hubei, China
[c] The Graduate Department, Wuhan Sports University, Wuhan, Hubei, China
[d] Department of Medical Affairs, Wuhan Maternal and Child Healthcare Hospital, Wuhan, Hubei, China
[e] Department of Rehabilitation Medicine, Zhongnan Hospital of Wuhan University, Wuhan, Hubei, China

ARTICLE INFO

Keywords:
Kinesio taping
Lower extremity
Meta-analysis
Rehabilitation
Stroke
Systematic review

ABSTRACT

Background: and purpose: The benefits of Kinesio taping (KT) in post-stroke rehabilitation have not been determined. This study aimed to evaluate its effects on lower-extremity rehabilitation in patients after a stroke.
Methods: A literature search was performed using EBSCOhost, Embase, Physiotherapy Evidence Database (PEDro), PubMed, Cochrane, Web of Science, China National Knowledge Infrastructure (CNKI), SinoMed, and Wanfang Data through June 2018. Randomized controlled trials (RCTs) on the use of KT during lower-extremity, post-stroke rehabilitation were selected. Meta-analysis was conducted.
Results: A total of 14 RCTs of low to moderate quality were reviewed and included 783 participants. Results indicated that KT significantly improved patients' lower extremity spasticity, motor function, balance, ambulation, gait parameters, and daily activities, with few adverse effects.
Conclusion: KT may have positive effects on lower-extremity, post-stroke rehabilitation. Due to the limited number and quality of the research, additional studies are needed to identify KT benefits.

1. Introduction

Many post-stroke patients experience varying types and degrees of impairment and even premature death, which leads to a loss of 102.2 million disability-adjusted life-years [1]. Patients who have lower-extremity dysfunction may not be able to live independently, which requires more health care support resources. Increased expenditures may impose a large burden on patients and families as well as on society as a whole [2,3]. To address these issues, health professionals should identify appropriate techniques that improve lower-extremity function of post-stroke patients to help them achieve independence and improve their quality of life [4].

Kinesio taping (KT) has been widely used in rehabilitation since it was developed by Dr. Kenzo Kase in 1979 [5]. This technique involves applying highly elastic tape to the skin of the affected body part to reduce mechanical constraints while providing additional support. It was believed to facilitate treatment outcomes by promoting lymphatic circulation, reducing pain, providing mechanical support, and improving proprioception [5]. Because the tape is thinner and more elastic than conventional tape, it is believed to lessen physical restraint and allow for greater mobility [6]. With continuing innovations and advances in rehabilitation methods, KT has been incorporated into post-stroke programs to enhance outcomes. However, its effectiveness has not been extensively researched or supported.

A systematic review conducted by Morris et al. [7] analyzed the effectiveness of KT in multiple clinical conditions and found inadequate clinical evidence that supports the superiority of KT compared to other interventions. This review included one study of post-stroke patients. A Spanish review noted that KT might benefit upper- and lower-extremity rehabilitation and swallowing function in patients after a stroke [8].

This systematic review was completed to augment the limited number of studies on KT use in post-stroke patients and the quality of this research. The focus was to address the benefits of KT in improving lower-extremity rehabilitation outcomes for post-stroke patients to include muscle tone, motor function, balance, gait parameters, and activities of daily living (ADLs).

2. Methods

The principles of the Preferred Reporting Items for Systematic

* Corresponding author. School of Health Sciences, Wuhan University, No. 115, Donghu Road, Wuhan, Hubei Province, 430071, China.
E-mail address: 846730310@qq.com (X.-l. Chen).

https://doi.org/10.1016/j.ctcp.2019.01.008
Received 31 July 2018; Received in revised form 12 January 2019; Accepted 14 January 2019
1744-3881/ © 2019 Elsevier Ltd. All rights reserved.

Table 1
Sample of search strategy.

Database	Search term
PubMed	#1 Kinesio[All Fields] #2 Kinesio tape[All Fields] #3 Kinesio taping[All Fields] #4 Kinesiotape[All Fields] #5 Kinesiotaping[All Fields] #6 Kinesiology tape[All Fields] #7 Kinesiology taping[All Fields] #8 Kinesio tex taping[All Fields] #9 #1 OR #2 OR #3 OR #4 OR #5 OR #6 OR #7 OR #8 #10 Stroke[MeSH Terms] #11 Cerebrovascular accident[MeSH Terms] #12 Apoplexy[MeSH Terms] #13 Hemiparesis[MeSH Terms] #14 #10 OR #11 OR #12 OR #13 #15 #9 AND #14

Abbreviations: MeSH, medical subject headings.

Reviews and Meta-analyses (PRISMA) guidelines were used to guide this systematic review [9].

2.1. Search strategy

A search of the literature for studies investigating the application of Kinesio tape in the rehabilitation of post-stroke patients was conducted through June 30, 2018. Nine databases were selected, including EBSCOhost, Embase, PEDro, PubMed, Cochrane Central Register of Controlled Trials (CENTRAL), Web of Science, China National Knowledge Infrastructure (CNKI), SinoMed, and Wanfang Data. The search used a combination of free and medical subject headings (MeSH) terms in the international databases and corresponding key Chinese terms in the Chinese databases. The exemplary search strategy of PubMed is presented in Table 1. References of included studies were manually searched for additional studies. Only peer-reviewed publications in English and Chinese were included in this review.

2.2. Inclusion and exclusion criteria

Inclusion criteria of participants (P), interventions (I), comparisons (C), outcomes (O), and study design (S) formation were as follows:

P: Adults (18 years of age or older) having had a stroke with functional impairments;
I: KT, with or without conventional rehabilitation treatment;
C: Conventional rehabilitation alone, conventional rehabilitation treatment in combination with placebo intervention (sham taping), or blank comparison;
O: Primary outcomes of changes in lower-extremity spasticity, lower-extremity movement, balance, ambulation, and gait parameters; secondary outcomes of improved ADLs and reported adverse effects;
S: Randomized controlled trials (RCTs) and pilot studies that applied a randomized controlled design.

Exclusion criteria were studies that comprised taping techniques other than KT and the use of medications affecting neuromuscular function (e.g., botulinum toxin).

2.3. Data extraction

Information was extracted by two reviewers (MW and ZP) independently using a standard form. Cross-checking was performed to validate data. A third reviewer (BX) was invited to participate to achieve consensus when there was disagreement between reviewers.

2.4. Risk of bias assessment

Included studies were assessed according to the Cochrane Handbook, version 5.1.0, for the risk of bias in seven domains: random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessors, incomplete outcome, selective reporting, and other bias [10]. Each study was appraised for low, high, or unclear risk. The risk of bias assessment was conducted independently by the two reviewers.

2.5. Data analysis and findings synthesis

Outcome data reported in two or more studies and presented with mean and standard deviation were pooled in the meta-analysis, using Review Manager 5.3 software offered by the Cochrane Collaboration. Only the last measured data were used when a repeat-measures design was adopted by certain included studies. Mean differences (MD) or standardized mean differences (SMD) with a 95% confidence interval (CI) were calculated for the results. Statistical heterogeneity between studies was evaluated by using the Chi-squared test in combination with I^2 values. Low heterogeneity would be achieved with a p value of the Chi-squared test > 0.10 and $I^2 < 50\%$, whereas high heterogeneity would be considered with a $p < 0.10$ and $I^2 \geq 50\%$. Fixed-effects models were used for low heterogeneity and random-effects models were used for high heterogeneity. Narrative description was used when meta-analysis was not applicable.

3. Results

3.1. Overview of included studies

The initial search yielded 103 records and, after review, it was determined that 14 Studies fulfilled the eligibility criteria and were included for data synthesis. Details of the selection process are illustrated in Fig. 1, and characteristics of included studies are summarized in Table 2. The included studies were published from 2014 through 2018. Most of the studies [11–21] (n = 11, 79%) were conducted in China, and the remainder were done in South Korea [22,23] (n = 2, 14%) and Iran [24] (n = 1, 7%).

The studies included 783 participants, with sample sizes ranging from 30 to 80. The study attrition rates were zero except for one [12] that reported a low rate.

3.2. Risk of bias in individual studies

The risk of bias summary is shown in Figs. 2 and 3. Most of the studies [11,13–16,18–24] (n = 12, 86%) were classified as moderate methodological quality because of unclear reporting of one or more aspects of the bias assessment, and no high-quality study was identified. Two studies [12,17] (14%) were of low methodological quality because each had one aspect rated as high risk. Inadequate reporting of information for risk of bias assessment in most of the seven domains was a common problem among the studies.

3.3. Characteristics of participants

In studies [11,12,14–22,24] (n = 12, 86%) that provided mean age data, the participants were, on average, 58.79 years of age. One study [13] reported the range of participants' ages without mean or median: participants' ages were from 33 to 80 years in the experimental group, whereas the ages of participants in the control group were from 35 to 78 years. One study [23] did not report participants' ages. Twelve studies [11–21,24] (86%) reported gender composition of participants with a larger proportion of males than females (55.7% vs. 44.3%). The period of time from when the participants were diagnosed as having had a stroke varied from five days to longer than 12 months.

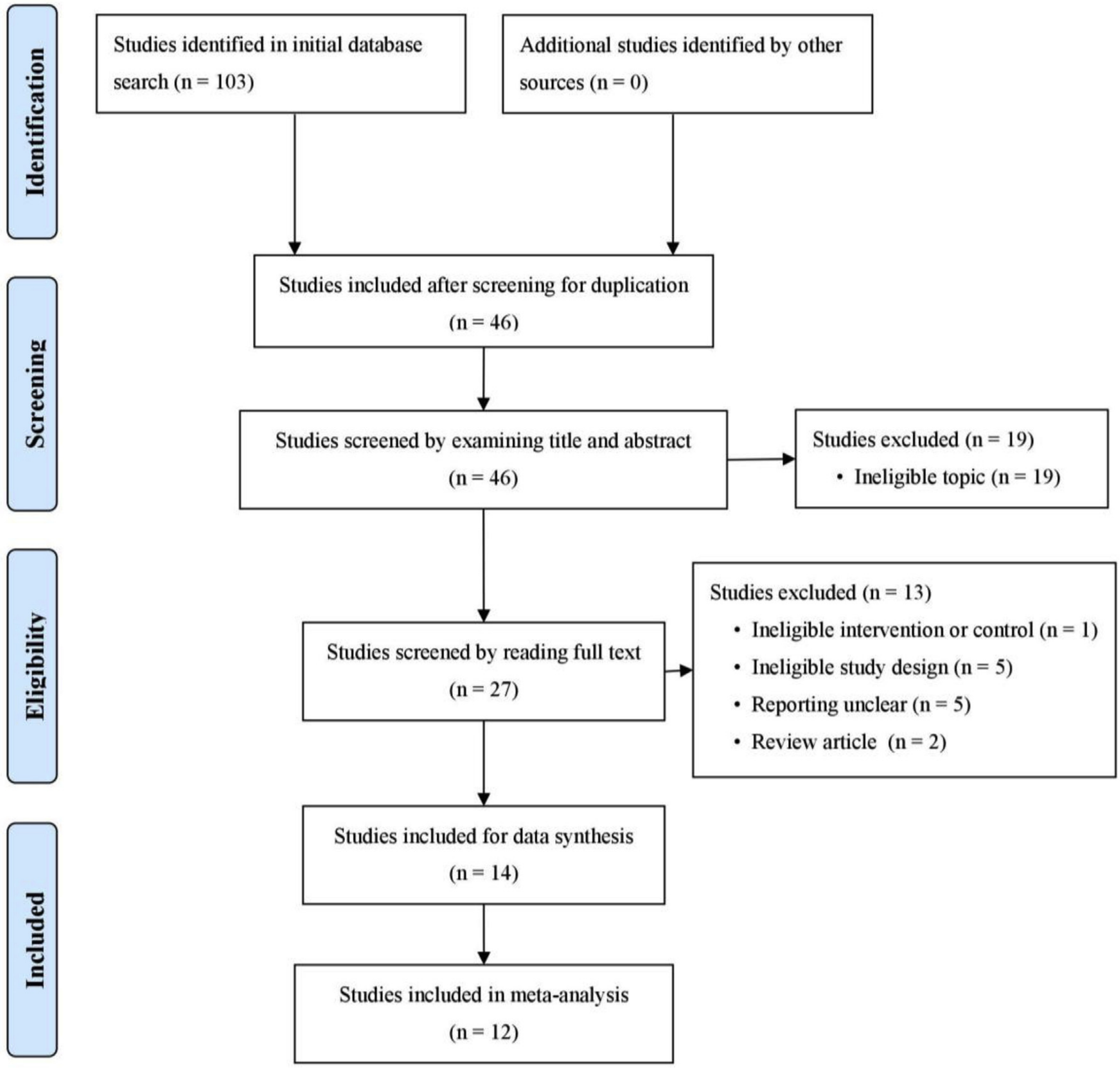

Fig. 1. PRISMA flow diagram of systematic review study selection process. Adapted from: http://www.prisma-statement.org/. EBSCOhost (n = 18), Embase (n = 6), PEDro (n = 8), PubMed (n = 6), Cochrane Library Central Register of Controlled Trials (n = 5), Web of Science (n = 9), CNKI (n = 17), SinoMed (n = 11), Wanfang Data (n = 23).

3.4. Characteristics of intervention

Kinesio taping was delivered by therapists in inpatient settings in most of the studies [11–21,23] (n = 12, 86%). Two studies [22,24] did not report where KT was done. More than 80% of the studies [11–21,23] used KT as an adjunct intervention in combination with conventional rehabilitation. Two studies [22,24] evaluated the effects of KT without other treatment. Conventional rehabilitation techniques used with both the experimental and control groups in the studies included physical therapy and occupational therapy. The use of KT in each study ranged from less than 24 h to three months. Only two studies [22,23] used either sham taping or another non-elastic taping technique for placebo comparison.

3.5. Outcome measures

Objective measurement scales with established validity and reliability were used in the majority of studies [12–24] (n = 13, 93%) for assessing comprehensive rehabilitation outcomes. Task and performance-based measures were mainly used to evaluate participants' balance and mobility. Gait parameters were analyzed in two studies [11,21].

3.6. Primary outcomes

3.6.1. Lower-extremity spasticity

Two studies [12,17] investigated the effect of five days of KT, in combination with conventional rehabilitation, on spasticity of the lower extremity, using the Modified Ashworth Scale (MAS). The result of fixed model meta-analysis showed that participants in the KT group had significantly lower MAS scores than those treated using only conventional rehabilitation in the control group [MD = −0.32, 95% CI (−0.53, −0.10), $p = 0.004$], with low heterogeneity between the studies (Chi^2 = 0.81, $p = 0.37$, $I^2 = 0\%$; see Fig. 4). One study [14] suggested that MAS outcomes of participants in the experimental group treated with KT plus conventional rehabilitation were significantly better than participants in the control group treated with only conventional rehabilitation after a three-month period ($p < 0.01$).

3.6.2. Lower-extremity motor function

Eight studies [13–16,18–21] explored the effectiveness of KT in improving scores on the Fugl-Meyer Assessment for Lower Extremity (FMA-LE) in participants, post-stroke. Because high heterogeneity was detected among the studies, meta-analysis was conducted using a random-effects model, with results indicating that the experimental

Table 2
Description of studies that were finally included in the review.

Study/Location	Participants	Intervention	Comparison	Outcome measure	Timing of assessment
Bae et al. (2015) South Korea	Total sample size (n = 30): EG (n = 15); CG (n = 15) Age (years): mean (SD): EG: 65.08 (9.33); CG: 63.50 (5.90) Gender (male/female): NR Stroke onset: in the past 3 months	KT application: on skin, without stretch, over fibularis longus, fibularis tertius, extensor digitorum longus, and tibialis anterior after maximal extension of these muscles and around ankle from foot to knee on affected side	Placebo taping: inflexible tape on front of lower leg on affected side	BBS, COP, LOS	Baseline; during
Chen et al. (2018) China	Total sample size (n = 72): EG (n = 36); CG (n = 36) Age (years): mean (SD): EG: 68.74 (5.36); CG: 67.93 (5.63) Gender (male/female): EG: 23/13; CG: 21/15 Stroke onset: mean (SD): EG (days): 17.96 (3.65); CG (days): 16.53 (2.54)	KT application: I-shaped strips, on affected leg, from upper part of lateral tibia, around ankle joint to medialis pedis, with 25% tension; Y-shaped strips, from planta pedis, along gastrocnemius, to internal and lateral condyle of femur, with 15% tension, kept for 24 h per day, for 3 months; Conventional rehabilitation including postural placement, stretching, and motor relearning training	Conventional rehabilitation including postural placement, stretching, and motor relearning training	MAS, FMA-LE, 10MWT	Baseline; 3 months
Choi et al. (2016) South Korea	Total sample size (n = 36): EG 1 (n = 12); EG 2 (n = 12); CG (n = 12) Age: NR Gender (male/female): NR Stroke onset: more than 6 months	KT application: covered rectus femoris muscle and the tensor fasciae latae from tuberosity of the tibia to inferior anterior iliac spine on affected side; Proprioceptive neuromusclar facilitation (PNF) therapy, 30 min, 3 times per week, for 8 weeks in total	***Experimental group 2:***Non-elastic Mcconnell taping covered over rear medial semitendinous muscle from lateral kneecap to inside on affected side; PNF therapy, 30 min, 3 times per week, for 8 weeks in total ***Control group:***PNF therapy, 30 min, 3 times per week, for 8 weeks in total	BBS, 10MWT	Baseline; 4 weeks; 8 weeks
Jia et al. (2016) China	Total sample size (n = 70): EG (n = 35); CG (n = 35) Age (years): mean (SD): EG: 50.92 (4.71); CG: 51.93 (4.71) Gender (male/female): EG: 18/17; CG: 19/16 Stroke onset: mean (SD): EG (months): 1.72 (0.35); CG (months): 1.96 (0.27)	KT application: on affected ankle joint and muscles with natural tension, replaced every other day, for 4 weeks; Conventional rehabilitation, 60 min per day, 6 days per week, for 4 weeks	Conventional rehabilitation, 60 min per day, 6 days per week, for 4 weeks	TUGT, 10mMWS, FMA-LE	Baseline; 4 weeks
Liu et al. (2016) China	Total sample size (n = 59): EG (n = 32); CG (n = 27) Age (years): mean (SD): EG: 63.92 (3.60); CG: 64.20 (4.1) Gender (male/female): EG: 20/12; CG: 18/9 Stroke onset: mean (SD): EG (days): 23.50 (5.62); CG (days): 21.80 (6.40)	KT application: I— and Y-shaped strips, on affected leg, from tibial tuberosity to medial femoral condyle, with 30% tension, kept for 24–48 h, every other day, for 8 weeks; Conventional rehabilitation, 40 min per day, for 8 weeks	Conventional rehabilitation, 40 min per day, for 8 weeks	FMA-LE	Baseline; 8 weeks
Lu et al. (2014) China	Total sample size (n = 80): EG (n = 40); CG (n = 40) Age (years): mean (SD): EG: 59.13 (11.60); CG: 59.18 (11.46) Gender (male/female): EG: 19/21; CG: 17/23 Stroke onset: mean (SD):	KT application: Y— shaped strips, on affected side, from heel to condylus medialis femoris and condylus lateralis femoris with 10%–20% tension, and I-shaped strips, from lateral surface of tibia to inside of front foot with 20%–30% tension, kept for 24 h per day; Conventional rehabilitation	Conventional rehabilitation	BI, MAS, BRS	Baseline; 1 day; 3 days; 5 days

(*continued on next page*)

Table 2 (*continued*)

Study/Location	Participants	Intervention	Comparison	Outcome measure	Timing of assessment
	EG (months): 2.7; CG (months): 2.6				
Rojhani-Shirazi et al. (2015) Iran	Total sample size (n = 40): EG (n = 20); CG (n = 20) Age (years): mean (SD): EG: 49.3 (9.3); CG: 10.6 (49.3) Gender (male/female): EG: 14/6; CG: 11/9 Stroke onset: mean (SD): EG (years): 1.4 (0.8); CG (years): 1.2 (0.5)	KT application: I strips, crossed over affected side ankle joint from proximal to distal with full tension	Without taping	FRT, LRT, BBS, TUGT, COP	Baseline; 24 h
Song et al. (2018) China	Total sample size (n = 60): EG (n = 30); CG (n = 30) Age (years): mean (SD): EG: 60.03 (8.56); CG: 61.63 (9.56) Gender (male/female): EG: 16/14; CG: 18/12 Stroke onset: EG (days): 39.20 (17.14); CG (days): 37.90 (18.40)	KT application: I strips, from lateral tibia, downward along anterior tibia muscle and bypass ankle joint, with natural tension, to medialis pedis for promoting tibia anterior muscle contraction; or from the small fibular head to the lateral malleolus, with natural tension, downward to medialis pedis for promoting contraction of the fibular jangdan muscle; Y-shaped strips, from medialis pedis, across posterior malleolus, upward to medial and lateral condyle of femur with natural tension; every other day, for 4 weeks Conventional rehabilitation, including postural placement, stretching, motor control training, and activities of daily living training, 30 min per time, 2 times a day, 6 days per week, for 4 weeks	Conventional rehabilitation, including postural placement, stretching, motor control training, and activities of daily living training, 30 min per time, 2 times a day, 6 days per week, for 4 weeks	FMA-LE, BRS, FAC, BI	Baseline; 4 weeks
Tan et al. (2016) China	Total sample size (n = 38): EG (n = 19); CG (n = 19) Age (years): mean (SD): EG: 60.3 (7.9); CG: 58.3 (8.9) Gender (male/female): EG: 7/12; CG: 9/10 Stroke onset: EG (days): 56.9 (16.5); CG (days): 58.2 (14.6)	KT application: I— and Y-shaped strips, on affected calf muscles, ankle joint, and foot, with 10%–40% tension; Conventional rehabilitation, 30 min per time, 2 times a day, 5 days per week, for 1 month	Conventional rehabilitation, 30 min per time, 2 times a day, 5 days per week, for 1 month	GA	Baseline; 1 month
Wu et al. (2017) China	Total sample size (n = 78) EG (n = 38); CG (n = 40) Attrition: EG (n = 2); CG (n = 0) Age (years): mean (SD): EG: 56.20 (8.31); CG: 54.60 (9.16) Gender (male/female): EG: 22/16; CG: 25/15 Stroke onset: EG (days): 5.98 (2.28); CG (days): 6.35 (2.43)	KT application: Y— and I-shaped strips, on affected quadriceps femoris, triceps surae, and musculi hippicus, with natural tension, 1 time a day, for 5 days; Conventional rehabilitation treatment, 30 min per time, 1 time a day, for 5 days	Conventional rehabilitation treatment, 30 min per time, 1 time a day, for 5 days	MAS, BBS, TUGT	Baseline; 5 days
Xia et al. (2015) China	Total sample size (n = 40): EG (n = 20); CG (n = 20) Age (years): mean (SD): EG: 52.20 (3.94); CG: 52.20 (4.49) Gender (male/female): EG: 15/5; CG: 14/6 Stroke onset: mean (SD):	KT application: on affected ankle joint and calf muscles, with natural or moderate tension, replaced every other day, for 4 weeks; Conventional rehabilitation, 60 min per day, 6 days per week, for 4 weeks	Conventional rehabilitation, 60 min per day, 6 days per week, for 4 weeks	TUGT, 10mMWS, FMA-LE	Baseline; 4 weeks

(*continued on next page*)

Table 2 (*continued*)

Study/Location	Participants	Intervention	Comparison	Outcome measure	Timing of assessment
	EG (months): 1.82 (1.29); CG (months): 2.20 (0.71)				
Xie et al. (2016) China	Total sample size (n = 80): EG (n = 40); CG (n = 40) Age (years): mean (SD): EG: 55.32 (13.21); CG: 56.36 (12.11) Gender (male/female): EG: 24/16; CG: 18/22 Stroke onset: mean (SD): EG (days): 31.55 (12.05); CG (days): 33.18 (10.11)	KT application: I— and Y-shaped strips, with natural or moderate tension, on affected knee joint and quadriceps femoris, tibialis anterior, and triceps surae muscles, kept for 24 h, 6 days per week, for 12 weeks; Conventional rehabilitation	Conventional rehabilitation	FMA-LE, FAC	Baseline; 12 weeks
Xu et al. (2016) China	Total sample size (n = 60): EG (n = 30); CG (n = 30) Age (years): mean (SD): EG: 64.40 (10.23); CG: 66.26 (10.00) Gender (male/female): EG: 18/12; CG: 16/14 Stroke onset: mean (SD): EG (days): 87.70 (36.31); CG (days): 92.83 (40.21)	KT application: I— and Y-shaped strips, on affected triceps surae, fibularis longus, and tibialis anterior muscles, kept for 48 h per time, 3 times per week, for 8 weeks; Conventional rehabilitation, 60 min per day, 5 days per week, for 8 weeks	Conventional rehabilitation, 60 min per day, 5 days per week, for 8 weeks	FMA-LE, FAC, GA	Baseline; 8 weeks
Zhang et al. (2015) China	Total sample size (n = 40): EG (n = 20); CG (n = 20) Age (years): range: EG: 33 to 80; CG: 35 to 78 Gender (male/female): EG: 11/9; CG: 10/10 Stroke onset: more than 12 months	KT application: on affected ankle joint and calf muscles, with natural or moderate tension, replaced every other day, for 4 weeks; Conventional rehabilitation	Conventional rehabilitation	TUGT, FMA-LE	Baseline; 4 weeks

Abbreviations: EG, experimental group; CG, control group; SD, standard deviation; KT, Kinesio taping; BBS, Burg Balance Scale; COP, center of pressure area; LOS, limits of stability; MAS, Modified Ashworth Scale; FMA-LE, Fugl-Meyer Assessment for Lower Extremity; 10MWT, 10 m walking test; TUGT, Timed Up and Go Test; 10mMWS, 10 m maximum walking speed; FAC, Functional Ambulation Category; BI, Barthel Index; BRS, Brunnstrom Recovery Stage; FRT, functional reach test; LRT, lateral reach test; GA, gait analysis.

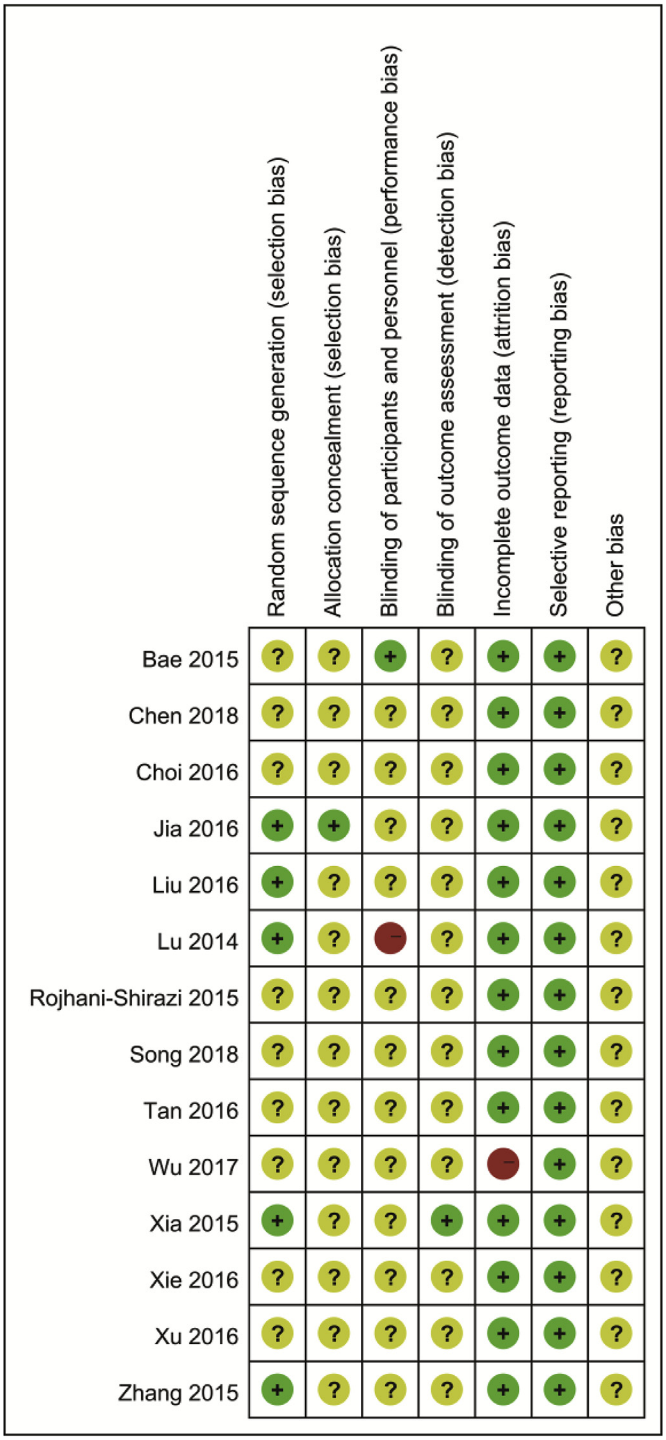

Fig. 2. Risk of bias summary: authors' judgment of bias item risks for each included study. "+": low risk, "?": unclear risk, and "-": high risk.

group treated with KT plus conventional rehabilitation achieved significantly higher FMA-LE scores than the conventional rehabilitation control group after four weeks [MD = 4.41, 95% CI (2.87, 5.96), $p < 0.00001$; $Chi^2 = 12.13$, $p = 0.007$, $I^2 = 75\%$], eight weeks [MD = 3.00, 95% CI (1.10, 4.89), $p = 0.002$; $Chi^2 = 0.29$, $p = 0.59$, $I^2 = 0\%$], and 12 weeks [MD = 8.26, 95% CI (2.66, 13.86), $p = 0.004$; $Chi^2 = 5.45$, $p = 0.02$, $I^2 = 82\%$] (Fig. 5).

In addition, the Lu et al. study [17] found no significant difference in the Brunnstrom Recovery Stage (BRS) of the lower extremities between KT plus conventional rehabilitation and conventional rehabilitation alone groups at days one, three, and five ($p > 0.05$). Another study [18] demonstrated improvement in the lower-extremity BRS in the KT plus conventional rehabilitation group compared with a conventional rehabilitation control group after four weeks of the intervention ($p < 0.05$).

3.6.3. Balance

Two studies [22,24] identified an immediate effect (within 24 h) of KT, compared with either placebo taping or blank control, on improving balance function of patients, post-stroke, using the Berg Balance Scale (BBS). The fixed-effects model ($Chi^2 = 0.43$, $p = 0.51$, $I^2 = 0\%$) meta-analysis showed no significant difference between the experimental and control groups [MD = −0.45, 95% CI (−3.35, 2.44), $p = 0.76$] (Fig. 6). Two additional studies [12,23] found that both five days and eight weeks of KT could improve BBS scores better than conventional rehabilitation in post-stroke patients ($p < 0.05$).

Bae et al. [22] and Rojhani-Shirazi et al. [24] also found that participants in a KT group achieved better outcomes in the center of pressure area ($p = 0.001$), limits of stability ($p = 0.000$), mediolateral displacement of center of pressure ($p = 0.04$), and forward reach ($p = 0.04$) tests during 24 h of intervention than those with or without placebo taping. However, no significant difference was found in other center of pressure tests ($p > 0.05$) and the lateral reach test ($p = 0.20$).

3.6.4. Ambulation

Three studies [18,20,21] examined the effect of KT on Functional Ambulation Category (FAC) scores in patients, post-stroke. Results of these studies suggested that participants in KT groups acquired higher FAC scores than did participants in the conventional rehabilitation control group after four to 12 weeks of intervention ($p < 0.05$). However, due to the inconsistent intervention duration of the studies, pooled data synthesis was not available.

Three studies [13,15,19] compared the difference between KT plus conventional rehabilitation and conventional rehabilitation alone in the Timed Up and Go Test (TUGT) after four weeks of intervention. The result of the fixed-effects model ($Chi^2 = 0.32$, $p = 0.85$, $I^2 = 0\%$) meta-analysis indicated that the time needed for participants to complete TUGT was significantly shorter in the KT group than in the control group [MD = −4.04, 95% CI (−5.07, −3.01), $p < 0.00001$] (Fig. 7). The Wu et al. study [12] further supported the advantage of five days of KT on stroke patients' TUGT performance ($p < 0.05$). However, an RCT conducted by researchers in Iran found no significant difference between participants treated with KT alone in the experimental group and participants without any treatment in the control group in TUGT ($p = 0.70$) after 24 h [24].

Two studies [15,19] examined the effect of four weeks of KT on the 10-m maximum walking speed test in stroke patients. Given the high heterogeneity ($Chi^2 = 10.00$, $p = 0.002$, $I^2 = 90\%$) between the studies, a random-effects model meta-analysis was used, with the result showing no significant difference between KT plus conventional rehabilitation and conventional rehabilitation alone [MD = 0.28, 95% CI (−0.01, 0.56), $p = 0.06$] (Fig. 8). Two other studies [14,23] demonstrated that four weeks ($p < 0.05$) up to three months ($p < 0.01$) of KT in combination with conventional rehabilitation may help stroke patients achieve better performance on the 10-m walking speed test than conventional rehabilitation alone would do.

3.6.5. Gait parameters

Two studies [11,21] evaluated the effect of KT on gait parameters. Both endorsed its positive effects on participants' gait velocity ($p < 0.05$) and step length of the affected side ($p < 0.05$) after receiving either one month or eight weeks of intervention. Tan and colleagues [11] further compared the stride frequency, step length of healthy side, gait cycle, stance period, and gait asymmetry index of the participants in the experimental and control groups. Results showed that all parameters of the experimental group treated with KT and

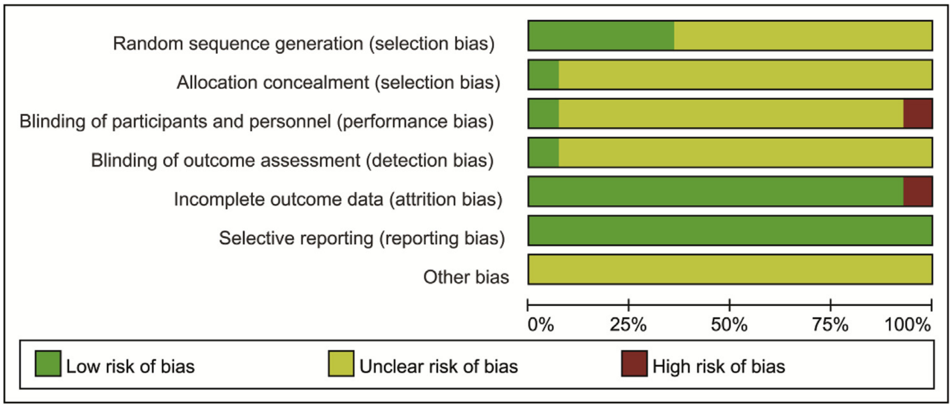

Fig. 3. Risk of bias graph: authors' judgment of item risks presented as percentages.

conventional rehabilitation were significantly better than those of the control group treated with conventional rehabilitation only ($p < 0.05$) after a one-month intervention. Xu et al. [21] also found that participants in the KT plus conventional rehabilitation group obtained better step width than those in the conventional rehabilitation group ($p < 0.05$) after eight weeks of intervention.

3.7. Secondary outcomes

3.7.1. Activities of daily living (ADLs)

Two studies [17,18] compared changes in the Barthel Index (BI) between participants receiving either KT plus conventional rehabilitation or conventional rehabilitation alone. The Lu et al. study [17] indicated no significant difference in BI between the two groups after one ($p = 0.774$), three ($p = 0.196$), and five days ($p = 0.062$) of intervention. Song et al. [18] found that participants in the KT plus conventional rehabilitation group achieved significantly higher BI scores than those in the conventional rehabilitation control group ($p < 0.05$) after four weeks.

3.7.2. Adverse effects

Allergy was indicated as an adverse effect in a few studies [20,23] (n = 2, 14%). One study [20] reported three cases of allergy in the experimental group during KT intervention, which were addressed by two to five days of anti-allergy treatment. Choi et al. [23] referred only to a potential for allergy and fatigue. Two studies [16,21] (14%) claimed that no side effect emerged during the research, whereas the remaining 10 studies [11–15,17–19,22,24] (72%) provided no information regarding adverse effects.

4. Discussion

This systematic review investigated the application of KT in lower-extremity rehabilitation after stroke; 14 studies involving 783 participants were included in this review. Results indicated that KT may benefit patients, post-stroke, in the improvement of lower-extremity spasticity, motor function, balance, ambulation, gait parameters, and ADLs, with few adverse effects. This is consistent with previous narrative review [8]. However, attention should be paid to the evidence generated from the current review due to a lack of high-quality studies.

The elastic tape used in KT can be tailored into shapes of "Y", "I", and "X" to fit the muscle and joint structure of the treated site [25]. Researchers implemented personalized KT based on the differences in lesion site and functional disorder for patients, post-stroke, according to their individual condition to maximize treatment effect. This may be a source of heterogeneity among the included studies. In addition, the manner of KT and the outcome measurements used in each study were varied, which led to difficulty in cross-study comparisons. Thus, sensitivity analysis and publication bias analysis were not available in this review.

One concern that arose in this review was the use of placebo taping to compare the effects of KT. Two studies [22,23] used non-elastic taping as a placebo in the control group. In previous systematic reviews, KT was not found to be superior to sham taping in control groups undergoing treatment for lymphedema related to breast cancer treatment and various musculoskeletal conditions, which could indicate a placebo effect [26,27]. To control for a placebo effect better, additional studies are needed to investigate the efficacy of KT versus the use of sham taping for comparison [27].

Short-term KT plus conventional rehabilitation for five days was considered beneficial for patients with stroke-related lower-extremity spasm in improving their MAS score. The effect size (MD = -0.32), however, was low according to the fixed-effects model meta-analysis; this may be due to the short course of treatment. Although one study [14] claimed the benefit of long-term KT application for three months in decreasing lower-extremity spasticity, the result is yet to be confirmed by additional trials.

Evidence demonstrated the usefulness of KT for motor function recovery of the lower extremity among patients after a stroke. It was hypothesized that applying KT on the skin would induce continuous muscle contraction and improve lymph and blood circulation, which may contribute to better joint movement [28]. The result of the meta-

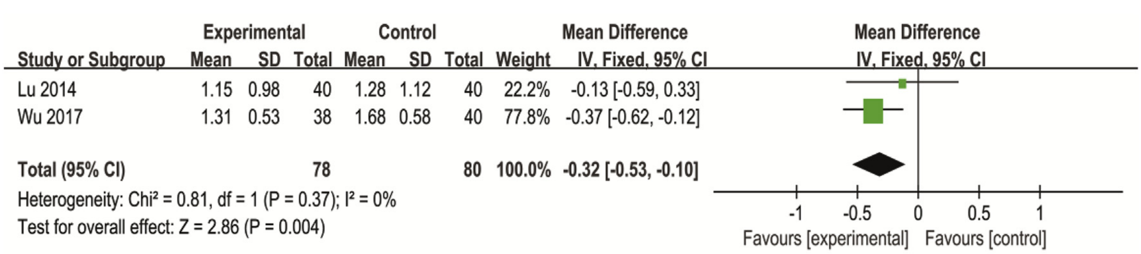

Fig. 4. Meta-analysis of difference in Modified Ashworth Scale scores between groups after intervention. Abbreviations: SD, Standard Deviation; IV, Inverse Variance; CI, Confidence Interval; df, degrees of freedom.

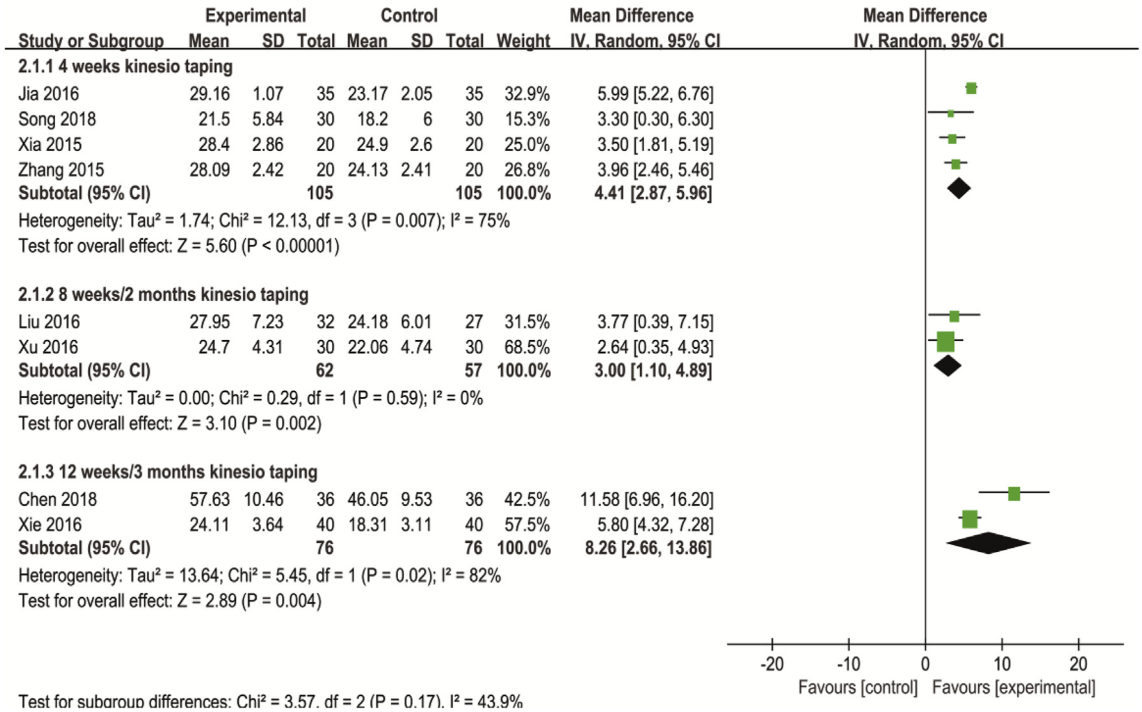

Fig. 5. Meta-analysis of difference in Fugl-Meyer Assessment for Lower Extremity scores between groups after intervention. Abbreviations: SD, Standard Deviation; IV, Inverse Variance; CI, Confidence Interval; df, degrees of freedom.

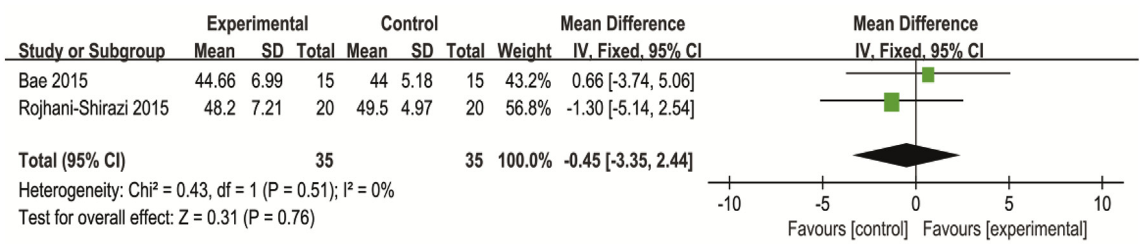

Fig. 6. Meta-analysis of difference in Berg Balance Scale scores between groups after intervention. Abbreviations: SD, Standard Deviation; IV, Inverse Variance; CI, Confidence Interval; df, degrees of freedom.

analysis indicated that the benefit was increased with prolonged duration of the intervention. This may be explained by the time effect of KT in stimulating the muscles and proprioceptors of the body [24]. However, the relationship between the duration and effectiveness of KT cannot be determined by this systematic review due to the limited number of included studies.

Positive effects of KT in enhancing balance function recovery were noted in a few studies, indicating that either a short-term or a long-term application of KT can make some difference. The improvement in balance may result from the additional support of KT on the ankle joint, which can facilitate movement control and joint stabilization [22,29]. However, the positive effects were limited due to the negative findings on some outcomes.

Five days or longer application of KT significantly improved ambulation after a stroke, whereas shorter duration of KT resulted in no significant difference. The improved lower-extremity spasticity, motor function, and balance after receiving KT may explain the increased ambulation capacity [30,31]. However, various outcome measures were used by the studies, a factor that limits a comparison between them. Thus, the total effect of KT on stroke patients' ambulation is not calculable in this systematic review.

Gait analysis indicated that KT in conjunction with conventional

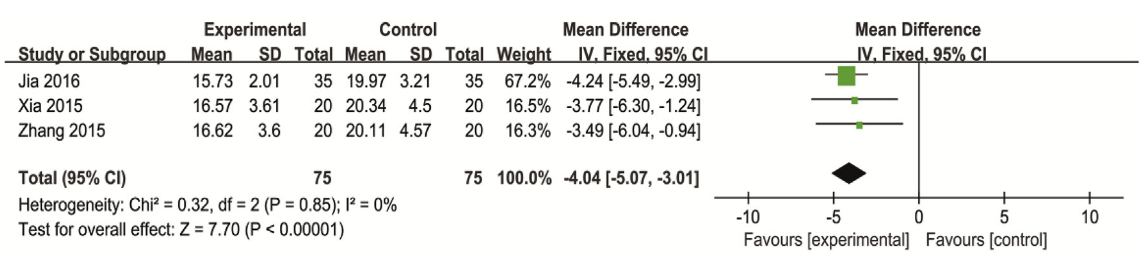

Fig. 7. Meta-analysis of difference in Timed Up and Go Test between groups after intervention. Abbreviations: SD, Standard Deviation; IV, Inverse Variance; CI, Confidence Interval; df, degrees of freedom.

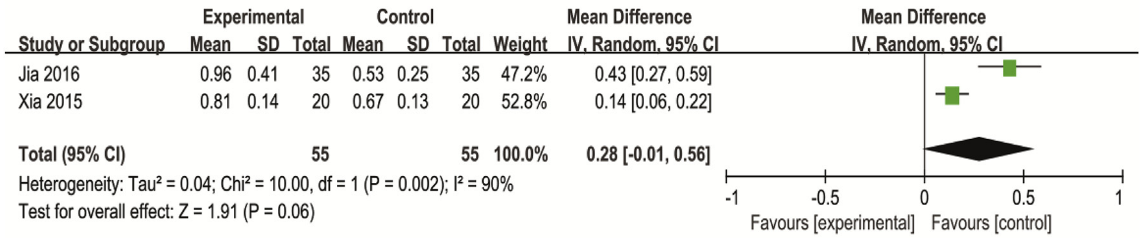

Fig. 8. Meta-analysis of difference in 10-m maximum walking speed between groups after intervention. Abbreviations: SD, Standard Deviation; IV, Inverse Variance; CI, Confidence Interval; df, degrees of freedom.

rehabilitation was superior to conventional therapy alone in correcting gait parameters after a stroke. Kinesio taping was believed to enhance muscle contraction of the tibialis anterior and prevent foot drop by means of its tension, which may be the cause of improved gait parameters after treatment [31,32]. Conclusive results cannot be verified because only two studies of moderate quality were included.

This systematic review also found that the complementary use of KT with conventional rehabilitation for eight weeks resulted in improvements in ADLs, whereas five days of KT plus conventional rehabilitation did not achieve a similarly positive effect. The reason may be related to the improvement in motor function, which suggested a time effect of KT intervention. Conclusions cannot be based on two studies of moderate methodological quality. Considering the multifactorial etiology and complexity of stroke-related alterations in ADLs, simple strategies may merely have limited effect size [33,34]. Further studies can integrate KT into more comprehensive intervention programs for ADL training.

Kinesio taping can be regarded as a safe intervention because adverse effects were seldom reported. Although some participants were at risk of allergy and fatigue during KT, the correlation between fatigue and KT was not clearly identified. To prevent allergic reactions, materials used in the manufacturing of Kinesio tapes should be modified.

Studies included in this review were conducted in Asia, primarily in China. This is possibly due to having a large stroke population but lacking medical resources in this region [35]. Interestingly, none of the studies evaluated the cost-effectiveness of KT in lower-extremity rehabilitation, post-stroke. Thus, an economic analysis is warranted before recommending KT in resource-limited settings.

5. Limitations

Limitations in this systematic review were identified. Due to limited translation resources, the publication language was restricted to English and Chinese by the eligibility criteria. This may be why none of the included studies originated in European countries. Of interest is a recent Spanish literature review that did not identify any study that was published in non-English languages [8]; this may reflect a minimized selection bias. Further systematic review without language constraint is warranted.

A lack of research with high methodological quality was a major problem in the current systematic review. Among the 14 included studies, none was identified as high-quality and no studies were conducted using a powered sample size. This limits the strength of evidence generated from this review. Sensitivity analysis and publication bias assessment were not performed because of the small number of included studies involving each outcome. Considering that both positive and negative results were reported, the risk of publication bias may not be severe across the studies. However, the heterogeneity among studies could not be addressed in this review, and the findings from the pooled meta-analyses are not generalizable.

6. Conclusion

This systematic review identified the positive effects of KT on lower-extremity spasticity, motor function, balance, ambulation, gait parameters, and ADLs in patients after a stroke. Adverse effects such as allergy to tape and fatigue occurred, but these are not considered major issues. Evidence supporting enhanced outcomes from the use of KT for post-stroke patients is limited. High-quality RCTs are needed to support its use. The cost-effectiveness of KT should also be determined in further study.

7. Implications for practice and research

The findings from this systematic review have implications for clinical practice. Because its efficacy in stroke rehabilitation remains unsupported by research, KT alone should not be recommended as a primary treatment for patients after a stroke. Considering a potential auxiliary effect, KT can be used as an assistive device during exercise training. Patients with a history of tape allergy or skin sensitivities should also be evaluated before considering KT.

Recommendations for further research include conducting high-quality studies using randomization and blinding following the Consolidated Standards of Reporting Trials statement. In addition, the effect size of KT and its correlation with the length of intervention duration should be investigated. Economic analysis is also needed in future studies to evaluate the cost-effectiveness of KT. Because none of the included studies were conducted in community settings, further research could explore the efficacy of KT for stoke patients in community- or home-based rehabilitation settings.

Conflicts of interest

The authors declare no conflicts of interest.

Contributions

Study Design: MW, ZP, XM, XC, and WL; Data Collection and Analysis: MW, ZP, and BX; and Manuscript Writing: MW, ZP, BX, XM, XC, and WL.

Acknowledgments

We greatly appreciate Dr. Scott Bickel and Dr. Deborah Lindell for their generous help in consultation and manuscript preparation, and we sincerely thank Dr. Sharon R. Redding for her generous help with revision and language editing. The authors received no financial support for the research, authorship, and/or publication of this article.

References

[1] V.L. Feigin, M.H. Forouzanfar, R. Krishnamurthi, G.A. Mensah, M. Connor, D.A. Bennett, A.E. Moran, R.L. Sacco, L. Anderson, T. Truelsen, M. O'Donnell, N. Venketasubramanian, S. Barker-Collo, C.M. Lawes, W. Wang, Y. Shinohara, E. Witt, M. Ezzati, M. Naghavi, C. Murray, Global burden of diseases, injuries, and risk factors study 2010 (GBD 2010) and the GBD stroke experts group, global and regional burden of stroke during 1990–2010: findings from the global burden of disease study 2010, Lancet 383 (9913) (2014) 245–255.

[2] H. Rigby, G. Gubitz, G. Eskes, Y. Reidy, C. Christian, V. Grover, S. Phillips, Caring for stroke survivors: baseline and 1-year determinants of caregiver burden, Int. J. Stroke 4 (3) (2009) 152–158, https://doi.org/10.1111/j.1747-4949.2009.00287.x.
[3] W. Wang, B. Jiang, H. Sun, X. Ru, D. Sun, L. Wang, L. Wang, Y. Jiang, Y. Li, Y. Wang, Z. Chen, S. Wu, Y. Zhang, D. Wang, Y. Wang, V.L. Feigin, NESS-China Investigators, Prevalence, incidence, and mortality of stroke in China: results from a nationwide population-based survey of 480,687 adults, Circulation 135 (8) (2017) 759–771, https://doi.org/10.1161/CIRCULATIONAHA.116.025250 Epub 2017 Jan 4.
[4] W.H. Chang, K.S. Min, J. Lee, D.Y. Kim, S.G. Lee, Y.I. Shin, G.J. Oh, Y.S. Lee, M.C. Joo, E.Y. Han, C. Kang, Y.H. Kim, Predictors of functional level and quality of life at 6 months after a first-ever stroke: the KOSCO study, J. Neurol. 263 (6) (2016) 1166–1177, https://doi.org/10.1007/s00415-016-8119-y Epub 2016 Apr 25.
[5] Kinesio Holding Corporation, History and Background, (2018) https://kinesiotaping.com/about/our-history/ , Accessed date: 29 July 2018.
[6] A.M. Castro-Sánchez, I.C. Lara-Palomo, G.A. Matarán-Peñarrocha, M. Fernández-Sánchez, N. Sánchez-Labraca, M. Arroyo-Morales, Kinesio Taping reduces disability and pain slightly in chronic non-specific low back pain: a randomised trial, J. Physiother. 58 (2) (2012) 89–95, https://doi.org/10.1016/S1836-9553(12)70088-7.
[7] D. Morris, D. Jones, H. Ryan, C.G. Ryan, The clinical effects of Kinesio® Tex taping: a systematic review, Physiother. Theory Pract. 29 (4) (2013) 259–270, https://doi.org/10.3109/09593985.2012.731675. Epub 2012 Oct 22.
[8] J. Ortiz-Ramirez, L.C.S. Perez-De, Efficacy of the application of Kinesio tape in patients with stroke, Rev. Neurol. 64 (4) (2017) 175–179.
[9] D. Moher, A. Liberati, J. Tetzlaff, D.G. Altman, PRISMA Group, Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement, BMJ 339 (2009) b2535, https://doi.org/10.1136/bmj.b2535.
[10] J. Higgins, S. Green, Cochrane Handbook for Systematic Reviews of Interventions, (2011) , Accessed date: 29 July 2018.
[11] T. Tan, X. Ye, Y. Yu, Y. Shao, Effects of Kinesio taping on gait in patients post stroke with hemiplegia, Chin. J. Rehabil. Med. 31 (6) (2016) 686–688, https://doi.org/10.3969/j.issn.1001-1242.2016.06.016.
[12] C. Wu, Y.L. Zhu, Q. Liu, R.R. Lu, Effects of Kinesio taping combined with physical training on lower extremity function in patients post stroke with hemiplegia, Chin. J. Rehabil. 32 (2) (2017) 131–132, https://doi.org/10.3870/zgkf.2017.02.013.
[13] X. Zhang, L.L. Du, B. Zhao, R.C. Song, Effects of Kinesio taping on ambulation dysfunction in hemiplegic stroke patients, Medinfo 28 (47) (2015) 81–82, https://doi.org/10.3969/j.issn.1006-1959.2015.47.107.
[14] Y. Chen, F. Xu, The effect of Kinesio taping combined with functional training on rehabilitation in patients post stroke, Neural. Inj. Funct. Reconstr. 13 (5) (2018) 265–266, https://doi.org/10.16780/j.cnki.sjssgncj.2018.05.017.
[15] D.P. Jia, L. Li, Z.Q. Wu, P.B. Ji, Effects of lower-extremity Kinesio taping on improving ambulation function in patients post stroke, Chin. Med. Device. 31 (Suppl) (2016) 80.
[16] Q. Liu, B. Yu, Q. Qi, Q. Tian, M. Jiang, W.H. Chen, Clinical effects of Kinesio taping for treating stroke patients with knee instability and degeneration, Geriatr. Health. Care. 22 (5) (2016) 303–305, https://doi.org/10.3969/j.issn.1008-8296.2016.05.12.
[17] J.M. Lu, T.H. Gao, J. Jia, C. Wu, R.R. Lu, J. Zhao, Y.Z. Xue, Effects of Kinesio taping on lower extremity function in stroke patients, Chin. J. Rehabil. Med. 29 (12) (2014) 1165–1167, https://doi.org/10.3969/j.issn.1001-1242.2014.12.015.
[18] W. Song, D.Q. Wang, Observation of therapeutic effect of Kinesio taping combined with rehabilitation training on stroke patients with foot drop, Chin. Foreign. Med. Res. 16 (4) (2018) 14–16, https://doi.org/10.14033/j.cnki.cfmr.2018.4.007.
[19] D.J. Xia, T. Peng, H.T. Wei, J. Yang, X.Y. Jiao, Y. Chen, Effects of Kinesio taping on ambulation function in patients post stroke with hemiplegia, Chin. J. Phys. Med. Rehabil. 37 (6) (2015) 427–429, https://doi.org/10.3760/cma.j.issn.0254-1424.2015.06.007.
[20] Z.L. Xie, S.W. Feng, Q.R. Cao, T.B. Deng, Y.C. Chen, J.W. Lin, S.Y. Huang, Z.B. Li, P. Liu, Application of Kinesio taping in the prevention of knee extension in patients with hemiplegia after stroke, Chin. J. Rehabil. 31 (2) (2016) 122–124, https://doi.org/10.3870/zgkf.2016.02.013.
[21] J. Xu, S.H. Hu, Y.F. Zhou, Q.Z. Chen, Q. Lin, Clinical observation of Kinesio taping with physical therapy on the lower limb function and walking ability in hemiplegic stroke patients, Chin. J. Rehabil. 31 (6) (2016) 446–449, https://doi.org/10.3870/zgkf.2016.06.012.
[22] Y.H. Bae, H.G. Kim, K.S. Min, S.M. Lee, Effects of lower-leg kinesiology taping on balance ability in stroke patients with foot drop, Evid. Based. Complement. Alternat. Med. 1 (2015) 125629, https://doi.org/10.1155/2015/125629. Epub 2015 Oct 22 (2015).
[23] Y.K. Choi, Y.H. Park, J.H. Lee, Effects of Kinesio taping and McConnell taping on balance and walking speed of hemiplegia patients, J. Phys. Ther. Sci. 28 (4) (2016) 1166–1169, https://doi.org/10.1589/jpts.28.1166. Epub 2016 Apr 28.
[24] Z. Rojhani-Shirazi, S. Amirian, N. Meftahi, Effects of ankle kinesio taping on postural control in stroke patients, J. Stroke Cerebrovasc. Dis. 24 (11) (2015) 2565–2671, https://doi.org/10.1016/j.jstrokecerebrovasdis.2015.07.008 Epub 2015 Aug 29.
[25] B. Kumbrink, Taping: an Illustrated Guide, Springer, Berlin, 2011, pp. 2–11.
[26] C. Parreira Pdo, C. Costa Lda, L.C. Hespanhol, A.D. Lopes, L.O. Costa, Current evidence does not support the use of Kinesio Taping in clinical practice: a systematic review, J. Physiother. 60 (1) (2014) 31–39, https://doi.org/10.1016/j.jphys.2013.12.008 Epub 2014 Apr 24.
[27] I. Saracoglu, Y. Emuk, F. Taspinar, Does taping in addition to physiotherapy improve the outcomes in subacromial impingement syndrome? A systematic review, Physiother. Theory Pract. 34 (4) (2018) 251–263, https://doi.org/10.1080/09593985.2017.1400138. Epub 2017 Nov 7.
[28] B. Boeskov, L.T. Carver, A. von Essen-Leise, M. Henriksen, Kinesthetic taping improves walking function in patients with stroke: a pilot cohort study, Top. Stroke Rehabil. 21 (6) (2014) 495–501, https://doi.org/10.1310/tsr2106-495.
[29] R.W. Bohannon, Taping for positioning and stabilizing the ankle of patients with hemiparesis. Suggestion from the field, Phys. Ther. 63 (4) (1983) 524–525.
[30] R. Barclay, J. Ripat, N. Mayo, Factors describing community ambulation after stroke: a mixed-methods study, Clin. Rehabil. 29 (5) (2015) 509–521, https://doi.org/10.1177/0269215514546769. Epub 2014 Aug 29.
[31] B.F. Koseoglu, A. Dogan, H.U. Tatli, D. Sezgin Ozcan, C.S. Polat, Can kinesio tape be used as an ankle training method in the rehabilitation of the stroke patients? Complement. Ther. Clin. Pract. 27 (2017) 46–51, https://doi.org/10.1016/j.ctcp.2017.03.002 Epub 2017 Mar 29.
[32] A. Słupik, M. Dwornik, D. Białoszewski, E. Zych, Effect of Kinesio Taping on bioelectrical activity of vastus medialis muscle. Preliminary report, Ortop. Traumatol. Rehabil. 9 (6) (2007) 644–651.
[33] J.M. Veerbeek, G. Kwakkel, E.E. van Wegen, J.C. Ket, M.W. Heymans, Early prediction of outcome of activities of daily living after stroke: a systematic review, Stroke 42 (5) (2011) 1482–1488, https://doi.org/10.1161/STROKEAHA.110.604090 Epub 2011 Apr 7.
[34] E. Andrenelli, E. Ippoliti, M. Coccia, M. Millevolte, B. Cicconi, L. Latini, G. Lagalla, L. Provinciali, M.G. Ceravolo, M. Capecci, Features and predictors of activity limitations and participation restriction 2 years after intensive rehabilitation following first-ever stroke, Eur. J. Phys. Rehabil. Med. 51 (5) (2015) 575–585 Epub 2015 Jan 23.
[35] A.S. Kim, E. Cahill, N.T. Cheng, Global stroke belt: geographic variation in stroke burden worldwide, Stroke 46 (12) (2015) 3564–3570, https://doi.org/10.1161/STROKEAHA.115.008226 Epub 2015 Oct 20.