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What is Effective for Fall Prevention Among Individuals Post-Stroke? A Systematic Review

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ABSTRACT

Background: Falls are a significant concern for people post-stroke. Interventions that effectively prevent or reduce the number of falls should be well documented and appraised for effectiveness. Therefore, our study aimed to identify and appraise the literature on interventions aimed at preventing or reducing falls among people post-stroke.

Methods: A comprehensive literature search was conducted in five databases. Two independent reviewers screened the literature search results to include relevant studies. Subsequently, reviewers extracted the data using a standardized form, and the quality of studies was assessed using a critical appraisal tool.

Results: 26 studies met the selection criteria and were included in our review. We identified eight categories for preventing and reducing falls. These categories were: electrotherapy, multifactorial fall prevention programs, educational programs, multifaceted stroke telerehabilitation, virtual reality, vitamin-D supplements, rehabilitation instruments, and physical activities.

Conclusion: The evidence for these interventions varied between studies, with no single intervention superior to others. The current review findings indicate that there is limited evidence to recommend one fall intervention to be generalized among people post-stroke. Further studies involving large sample sizes and different fall outcomes are needed to make valuable recommendations for clinical practice.

Keywords: Stroke, Falls, Balance, Interventions, Systematic Review.

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INTRODUCTION

One of the leading global causes of morbidity and mortality is stroke [1]. Studies indicate that over 70% of people post-stroke experience impairments that affect their quality of life and activities of daily living (ADLs) [1]. As such, rehabilitation of people post-stroke is of great importance and implies the need to develop better assessment methods and advance the effectiveness of therapeutic interventions for these individuals. Several impairments can be experienced following a stroke; however, impaired postural control is likely to cause the most significant impact on ADL independence and gait [2]. Furthermore, impaired postural control among stroke survivors leads to high falls during rehabilitation and afterward [3, 4]. It is estimated that the fall rate among people post-stroke in the hospital phase is between 14% to 65%, and in the few months following discharge, fall rates can reach up to 73% [5]. Thus, it is essential to address the issue of fall prevention among people post-stroke.

Fall prevention is substantial for individuals post-stroke, their caregivers, and society [5]. Common fall complications, such as hip fractures, result in high costs to the individual and society [5]. Other complications of falls include fear of falling, reduced participation in ADL, and social activities [6, 7]. There are several reported methods for fall prevention [8]. These include therapeutic exercise programs, assistive walking devices, functional electrical stimulation, and technologies such as robotics and virtual reality (VR) [8]. Various methods exist to detect and predict falls among people post-stroke [9, 10]. The calendar method has been validated and used successfully to report fall incidence among people post-stroke [9]. The fall efficacy scale (FES) is a reliable and valid questionnaire that contains 16 items to measure self-confidence in completing a range of ADLs without falling [10].

Further, postural balance is highly related to the incidence of falls. Therefore, postural balance is often impaired following stroke and should be properly evaluated to identify stroke patients who have a high risk of falling. The Berg balance scale (BBS) is one of the balance measures that is commonly used post-stroke, and it was reported to predict fall risk among stroke patients [11].

The importance of addressing falls among people post-stroke is because of the devastating consequences of falls on the individuals, both physically and psychologically [4, 12]. These consequences include head trauma, increased need for healthcare, increased admission to long-term care, premature disability, increased dependence, decreased socialization, and even death [4, 12]. In addition, there are a plethora of studies available related to fall prevention among people post-stoke. Therefore, there is a need to critically appraise the interventions available for preventing falls among individuals post-stroke. This systematic review aims to identify and appraise the literature on the available interventions related to fall prevention investigated among people post-stroke.

METHODS

Study design

A systematic review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines (PRISMA) [13].

Literature search

A comprehensive literature search was performed in five databases: PubMed, Embase, CINAHL, Scopus, and Web of Science. The search was for all available records up to May 2021. No limitations were placed on the search strategy. A specialized librarian was involved in the formulation of the search strategy. All searches were conducted in collaboration with a specialized librarian. The following keywords and Medical Subject Headings (MeSH) were used: (1) Stroke [MeSH] OR Hemiplegia [MeSH] OR Hemiparesis OR Cerebrovascular Accident OR CVA; (2) Accidental Falls [MeSH] OR Fall* OR Slips OR Trips. The searches in all databases were combined as 1 AND 2. Further, we searched reference lists of articles relevant to our objective to identify relevant studies.

Study selection and data extraction

For the selection of studies, two of our co-authors (F. A. and G. A.) independently reviewed the titles/abstracts for all the literature search results. Studies that appeared to be related to the topic of our review (falls and fall prevention) were kept for further inspection, and those unrelated were excluded. Subsequently, the full text of the retained articles was retrieved and reviewed by the same two reviewers independently to confirm if the studies could be included in our systematic review. The inclusion criteria were the following: (i) Participants included were adults (>18 years) and were diagnosed with stroke; (ii) the study was a randomized controlled trial; (iii) the study aimed to provide an intervention to prevent or reduce falls; (iv) Study reported at least one outcome measure that assesses falls and/or fall prevention; and, (v) Original research articles published in a peer-reviewed journal and written in English. A third senior reviewer adjudicated to reach an agreement in the disagreement between reviewers.

Data extraction of the articles that met the criteria was conducted by the same independent reviewers using a structured form. The information obtained from all studies included participants' characteristics, the objective of the study and intervention, outcome measures, and main findings.

Quality assessment of methodology for included studies

The methodology's quality assessment for included studies was performed using PEDro critical appraisal tool [14, 15]. The critical appraisal tool was performed by the same two reviewers independently. The 11-item critical appraisal scale evaluates the quality of the included studies. Each of the 11-items is scored as present or absent (i.e., 1 or 0) for a possible total score of 11. Previous systematic reviews related to assessment tools in rehabilitation have used the PEDro appraisal tool [5, 15]. A final consensus amongst all authors resolved any discrepancies.

RESULTS

The initial literature search yielded 13308 potentially relevant studies. After removing duplicates and screening titles/abstracts, 116 studies were retrieved to review their full text. Following the full-text review, 26 studies were included as they adhered to our inclusion criteria (Figure 1). The critical appraisal tool used in our review showed that the total scores of studies ranged from six to ten out of a maximum of 11 (Table 1). Items 1, 2, 4, 10, and 11 in the critical appraisal tool were consistently scored (1) by all the reviewed studies. Conversely, the reviewed studies scored items 3, 5, and 6 (1) by only 58%, 8% and 4%, respectively. None of the reviewed studies scored (1) in all items of the critical appraisal tool.

Figure 1: Flowchart of search and selection strategy

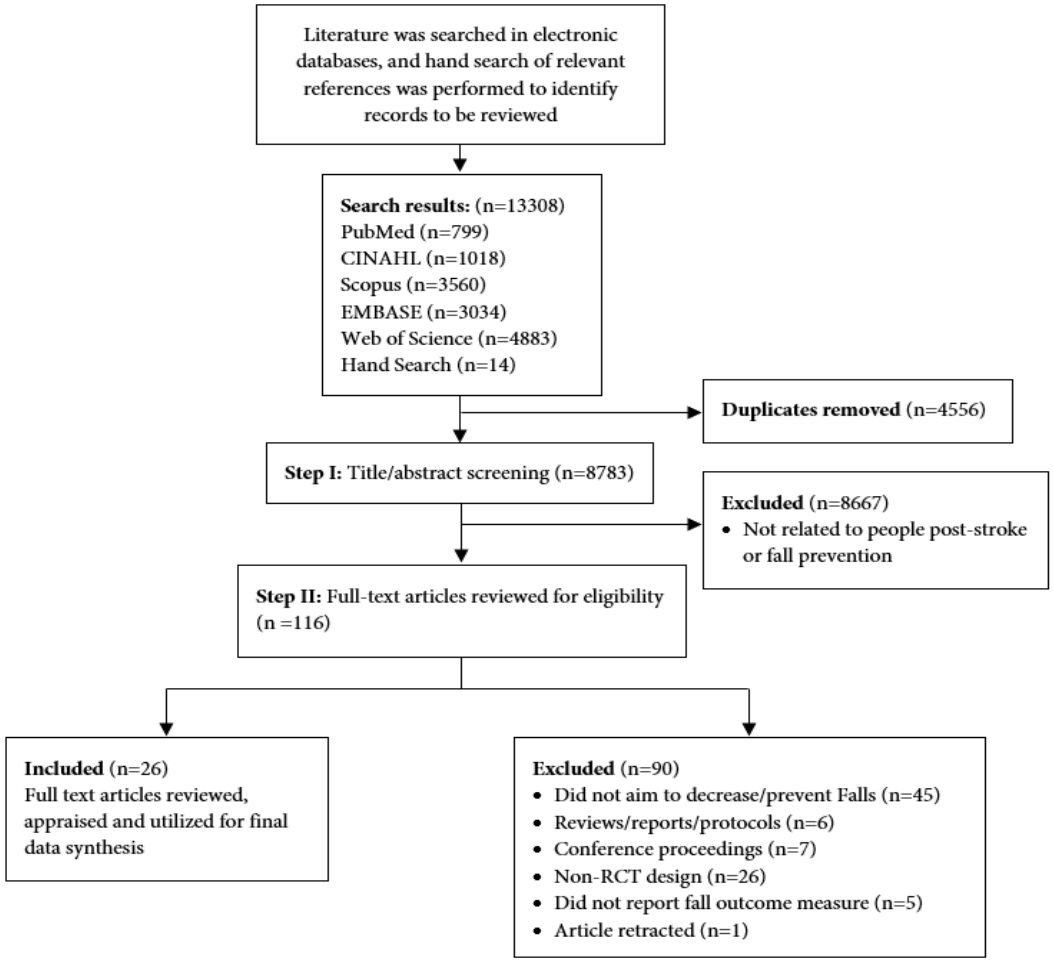

Table 1: Critical appraisal of included studies

Item evaluation criteria* (No: 0; Yes: 1)

Study	Item 1	Item 2	Item 3	Item 4	Item 5	Item 6	Item 7	Item 8	Item 9	Item 10	Item 11	Total
	Eligibility	Randomization	Concealment	Baseline	Subjects Blinding	Therapist Blinding	Assessor Blinding	Key Outcome	Intention To Treat	Between-group	Variability	
Andrade, et. al., 2017	1	1	1	1	1	0	1	1	1	1	1	10
Batchelor, et. al., 2012	1	1	1	1	0	0	1	1	1	1	1	9
Cattaneo, et. al., 2019	1	1	0	1	0	0	1	1	1	1	1	8
Cheng, et. al., 2001	1	1	0	1	0	0	0	1	0	1	1	6
Chumbler, et. al., 2015	1	1	1	1	0	0	1	1	1	1	1	9
Correia, et. al., 2021	1	1	0	1	0	0	0	1	1	1	1	7
Dean, et. al., 2012	1	1	1	1	0	0	1	1	1	1	1	9
da Fonseca, et. al., 2017	1	1	1	1	0	0	1	1	0	1	1	8

Hahn, et. al., 2015	1	1	0	1	0	0	0	1	0	1	1	6
Handelzalts, et. al., 2019	1	1	1	1	0	0	1	1	1	1	1	9
Holmgren, et. al., 2010	1	1	0	1	0	0	1	1	1	1	1	8
Hunag, et. al., 2019	1	1	1	1	0	0	1	1	1	1	1	9
Jung, et. al., 2015	1	1	0	1	0	0	0	1	0	1	1	6
Kim & Lim, 2017	1	1	0	1	0	0	1	1	0	1	1	7
Lau, et. al., 2012	1	1	1	1	0	0	1	1	1	1	1	9
Lee, et. al., 2018	1	1	0	1	0	0	1	1	0	1	1	7
Lee, et. al., 2019	1	1	0	1	0	0	0	1	0	1	1	6
Mansfield, et. al., 2018	1	1	0	1	0	0	1	1	1	1	1	8
Marigold, et. al., 2005	1	1	1	1	0	0	1	0	0	1	1	7
Morone, et. al.2016	1	1	1	1	0	0	1	1	0	1	1	8
Nikamp, et. al., 2019	1	1	1	1	0	0	0	1	0	1	1	7
Onal, et. al., 2020	1	1	1	1	0	0	0	1	0	1	1	7
Pang, et. al., 2018	1	1	1	1	0	0	1	1	1	1	1	9
Park, et. al., 2020	1	1	0	1	0	0	1	1	0	1	1	7
Sato, et. al., 2005	1	1	1	1	1	1	1	1	0	1	1	10
Taylor-Piliae, et al., 2014	1	1	1	1	0	0	1	1	1	1	1	9

*Item evaluation criteria: **Eligibility**: eligibility criteria were specified; **Randomization:** subjects were randomly allocated to groups (in a crossover study, subjects were randomly allocated an order in which treatments were received); **Concealment:** allocation was concealed; **Baseline:** the groups were similar at baseline regarding the most important prognostic indicators; **Subjects Blinding:** there was blinding of all subjects; **Therapist Blinding:** there was blinding of all therapists who administered the therapy; **Assessor Blinding:** there was blinding of all assessors who measured at least one key outcome; **Key Outcome:** measures of at least one key outcome were obtained from more than 85% of the subjects initially allocated to groups; **Intention To Treat:** all subjects for whom outcome measures were available received the treatment or control condition as allocated or, where this was not the case, data for at least one key outcome was analysed by "intention to treat"; **Between-group:** the results of between-group statistical comparisons are reported for at least one key outcome; **Variability:** the study provides both point measures and measures of variability for at least one key outcome.

Table 2 provides a summary of all the 26 included studies. A sum of 1619 participants was included in the studies, with 731 participants (45.2 %) receiving an experimental intervention. The remaining participants (54.8%) underwent control groups or received conventional therapy. All the included studies examined individuals post-stroke, except one study examined individuals with multiple sclerosis and Parkinson's disease in addition to people post-stroke. The participants' ages ranged from 50 to 87 years old. Most studies reported a relatively small sample size, with 25-60 participants. Only eight studies reported large sample sizes with more than 40 participants in each group. The setting for the trials alternated and included community settings, rehabilitation hospitals, physical therapy clinics, and homes.

Multiple fall outcome measures were utilized in the reviewed studies. Eight studies reported using the fall efficacy scale [16-23]. Four studies relied on the Biodex balance system, which can measure the risk of falls [24-27]. One study used the falling threshold [28] and the fall risk index [29]. Regarding reporting of falls, some studies reported falls using a fall calendar or a fall diary from 6 to 12 months. Other studies recorded falls as the number of falls in a given period or fall rates, or several fallers.

A variety of interventions that aimed to prevent falls were identified in the reviewed studies. These interventions ranged from direct (e.g., therapeutic exercises) to indirect (educational programs). These interventions were classified into eight categories and elaborated on below.

Table 2: Summary of Studies.

Study	Population	n	Objective	Fall Outcome Measure	Main Findings
Andrade, et al., 2017	First unilateral acute ischemic stroke	60	Analyze the effectiveness of different montages of tDCS on reducing falls and lower limb function compared to sham tDCS after acute stroke	-Faller n -Four square step test, -Overall stability index, -Biodex balance system	1- Treated groups had a rate of fall occurrence of zero 2- Treated groups had better scores in four square step test compared to the sham group 3- Based on overall stability index score, sham group had more fall risk in comparison to other participants
Batchelor, et al., 2012	Individuals post-stroke with high risk of fall	156	To determine whether a multifactorial falls prevention program compared to usual care reduces falls in people with stroke	-Fall rates, -Fall Efficacy scale	1- There were no differences between groups in fall rate 2- Over 12 months, results of fall risk showed that both groups improved significantly. 3- Intervention group that received the Otago exercise program showed significant improvement on fall - related efficacy.
Cattaneo, et al., 2019	Individuals with Stroke/ multiple sclerosis/Parkinson disease and able to walk 10m independently	25 stroke, 33 MS, 32 PD	To test whether an educational program focusing on fall prevention and safe mobility compared to usual care reduces falls and increases social participation	Percentage of fallers for 6 months	Education program in the study had no significant effect on risk of falls. However, educational program did improve participants capacity to perform activities of daily living and lessened participation restrictions among participants
Cheng, et al., 2001	Hemiplegic stroke occurred from 2 to 4 months	54	To determine the role of symmetrical body weight distribution training compared to usual care in preventing falls among patients with hemiplegic stroke.	Occurrence of falls at 6 months follow up	Results showed that at 6-moths follow-up participants in the training group had significantly less incidence of fall
Chumbler, et al., 2015	Stroke that occurred >24 months	52	To determine the effect of multifaceted stroke tele-rehabilitation intervention on falls related self-efficacy and satisfaction with care .	Falls Efficacy scale	Results showed no significant change in fall- related self-efficacy
Correia, et al., 2021	Stroke that happened 3-15 months and caused balance impairment. Participants able to walk at least 3 meters independently.	79	To assesses the effect of a domiciliary program of oculomotor and gaze stability exercises on the incidence of falls and on the risk of fall in stroke survivors	Number of fall for 3 weeks	Participants in the intervention cohort had less falling events compared to control; but change was not significant. However, the estimated risk of falling significantly diminished for both groups.
Dean, et al., 2012	Frist or recurrent stroke and able to walk independently 10 meters	151	To investigate whether an exercise intervention can enhance mobility, prevent falls, and increase physical activity compared to usual care among community dwelling people after stroke.	Number of falls for 1 year with monthly fall calendars	No significant differences between groups were found in terms of proportion of fallers or rate of falls.
da Fonseca, et al., 2017	Hemiparesis after stroke, age from 18 to 65 years.	27	To check the therapeutic effect of virtual reality associated with conventional physiotherapy compared to conventional therapy alone on gait balance and the occurrence of falls after a stroke.	Number of falls before and after 20 intervention sessions.	Results revealed that both groups after the study had lesser incidences of falls. However, only for the intervention group was this decrease statistically significant.
Hahn, et al., 2015	People post-stroke who are able to walk 2 minutes or more with or without assistive device.	24	To investigate the effects of modified trampoline training on the balance, gait, and falls efficacy compared to usual care among stroke patients.	Fall Efficacy Scale	A significant change in the outcome measures was found before and after treatment for trampoline group. Further, the change for trampoline group was also greater and statistically significant compared to control group.
Handelzalts, et al., 2019	First unilateral stroke and able to walk	34	To explore the effect of a short-term PBBT on reactive balance responses, performance-based measures of balance and gait and balance confidence.	Fall threshold	Results of fall-threshold showed no statistically significant differences between groups.
Holmgren, et al., 2010	Frist or recurrent stroke > 3-6 months and able to walk 10 meters	34	To evaluate a high intensive functional exercise program in stroke subjects with risk of falls regarding balance, activity of daily life, fall efficacy, number of falls and life style activity compared to a control group.	-Fall Efficacy Scale, -Number of fall for 6 months	1) No significant difference was found between experimental and control groups in number of falls 2) Results of fall efficacy scale showed that experimental group had greater improvement compared to control.

Hunag, et al., 2019	Diagnosis of cerebral haemorrhage or infarction, 30–75 years of age, with fear of falling, able to stand and walk with no experience of Tai Chi	28	To examined whether BWS-TC footwork training could enhance balance capability in stroke survivors.	FRI	Significant differences were identified following the intervention between the experimental and control groups. Those in BWS-TC group showed a non-significant reduction in outcome measures between start of intervention and after 12 weeks.
Jung, et al., 2015	Stroke within the previous year and able to walk independently.	25	To investigate the effects of multifactorial fall prevention program compared to a treadmill training group on balance, gait, and fear of falling among stroke patients.	Fall Efficacy Scale	Significant improvement was identified in fall efficacy scale score among the experimental group compared to control groups.
Kim & Lim, 2017	Frist onset hemiparetic stroke > 6 months, able to walk > 30 seconds	31	To examine the effects of Pedalo training compared to a treadmill training group on balance and fall risk in stroke patients.	Biodex Balance system	Risk of fall was significantly decreased among both groups and no significant difference was noticed between groups.
Lau, et al., 2012	Unilateral, chronic hemiparetic stroke > 6 months and able to stand independently at least 1.5 minutes	82	To examine the efficacy of whole body vibration compared to a control group in optimizing neuromotor performance and reducing falls in chronic stroke patients.	Fall-related-self efficacy.	1) No change was identified between groups in terms of incidence of falls 2) No change was found post-intervention for both groups in terms of proportion of fallers.
Lee, et al., 2018	Chronic hemiparetic stroke > 6 months and able to walk independently > 10 m	28	To compare the effects of conventional core stabilization and dynamic neuromuscular stabilization on anticipatory postural adjustment time , balance performance, and fear of falls in chronic stroke.	Fall Efficacy Scale	1) In the experimental group, the post-test fall efficacy scale score showed improvement compared to pre-test following therapy and also after 2 year follow-up 2)In the control group, the post-test fall efficacy scale score showed improvement following therapy but no retention of improvement at 2 year follow-up
Lee, et al., 2019	Chronic stroke > 3 months, able to walk more than 10 m without an assistive device.	45	To evaluate the effects of community based walking training compared to a treadmill training group on the walking ability and fall related self-efficacy of chronic stroke.	Fall-related-self efficacy.	Results showed that a community based walking program can improve the fall related self-efficacy significantly compared to treadmill walking training or no intervention.
Mansfield, et al., 2018	Chronic stroke > 6 months, able to stand independently without upper limb support for >30 seconds, tolerate at least 10 postural perturbations.	88	To determine if perturbation based balance training compared to a control group can reduce falls in daily life among individuals with chronic stroke.	Number of falls for 1 year	Results showed that both groups did not exhibit significant reduction in fall rates.
Marigold, et al., 2005	Single stroke, > 12 months, age ≥ 50 years, able to walk for 10 m and have activity tolerance of 60 minutes with rest intervals.	61	To determine the effect of two different community based group exercise programs on functional balance, mobility, postural reflexes and falls in older adult with stroke.	Number of falls for 1 year	Following therapy, decreased falls on platform were noticed for agility group but an increase in falls was noticed for stretching/weight-shifting group. There was also a non- significant decrease in the community-based falls between groups.
Morone, et al.2016	Hemiparesis following first unilateral stroke, (<90 days from onset), age from 18 to 80 years, ability to perform assisted walking training on the parallel bar.	44	To evaluate the effects of over-ground robotic walking training performed with the servo-assistive robotic rollator compared to a control group on walking balance, gait stability and falls in a community setting in patients with mild subacute stroke.	Number of fallers in the community setting after 6 months	Number of falls for robotic walking group was less than 50% of the control group but the difference was not significant.
Nikamp, et al., 2019	First stroke with unilateral hemiparesis, and indication for AFO use, < 6 weeks post-stroke, age > 18 years.	33	To study effects of AFO-provision on occurrence and circumstances of falls/ near falls.	Number of falls for 1 year	Results showed that early group had significantly more falls than delayed group in weeks 1-8, but no differences at 9-52 weeks
Onal, et al., 2020	Stroke occurred > 8 weeks, aged 45-75 years and able to stand and no cognitive problems.	30	To determine the immediate effect of local vibration applied to the plantar region on fall risk and postural stability in patients with stroke.	Biodex Balance System	Postural stability significantly improved following local vibration. Improvement occurred immediately (within 5 mins). Also, fall risk values significantly improved. No significant change was seen in placebo group

Pang, et al., 2018	Stroke ≥ 6 months, age ≥ 50 years, community dwelling, medically stable, having balance deficits, and able to walk at least 10 m without assistance.	84	To examine the effects of dual-task exercise compared to single task and control groups in chronic stroke patients.	Number of fall for 6 months	Lower proportion of fallers and falls were noticed in dual-task group compered to control during 6 months. For single task group, there were some improvements but not statistically significant.
Park, et al., 2020	Stroke occurred ≥6 months, PROM for ankle dorsiflexion <8° on the affected side, able to walk independently for 10 m without the use of assistive devices.	38	To compare the effects of 4-week self-mobilization with movement with those of calf muscle stretching on ankle dorsiflexion passive range of motion, gait parameters, and fall risk in patients with chronic stroke with limited ankle dorsiflexion	Biodex Balance System	Post-treatment a significant decrease was noticed in fall risk for self-mobilization with movement group compared to the other group.
Sato, et al., 2005	Elderly women with first stroke > 2 years ago and were in a convalescent stage with post-stroke hemiplegia.	96	To evaluate the efficacy of vitamin D2 therapy compared to placebo in reducing the risk of falls in elderly women with stroke.	Number of fall for 2 years.	Results suggested that vitamin-D supplements led to a decrease in recurrent falls.
Taylor-Piliae, et al., 2014	Community dwelling survivors of stroke ≥50 years who were > 3 months post-stroke.	145	To examine the effect of a 12 week Tai Chi intervention compared to SilverSneakers group and usual care on physical function, fall rates, and quality of life among a group of community dwelling older stroke survivors compared with strength and range of movement exercise and usual care.	Number of falls for 12 weeks	Tai Chi led to fewer falls (two thirds less) compared to other groups.

n: number; **tDCS**: transcranial direct current stimulation; **MS**: multiple sclerosis; **PD**: Parkinson's disease; **m**: meters; **PBBT**: Perturbation-Based Balance Training; **BWS-TC**: Body weight support-Tai Chi; **FRI**: Fall Risk Index; **AFO**: Ankle-Foot Orthosis; **PROM**: Passive range of motion.

Electrotherapeutic

One study reported using transcranial direct current stimulation (TDCS) at an intensity and current density of 2 mA and 0.05 A/m², respectively, for 30 seconds for a total of 10 sessions (2 weeks) in addition to a physical rehabilitation program. Results showed that TDCS improved motor recovery that was retained for more than three months following treatment. Also, it showed a significant decrease in the rate of falls compared to the sham-TDCS group [24].

Multifactorial fall prevention program

Two studies reported a multifactorial fall prevention program [16, 20]. Batchelor et al. (2012) reported an intervention that consisted of a home exercise program based on the Otago Exercise Program (OEP), strategies to minimize fall risk, education about factors related to fall risk, and strategies to minimize the risk of injury. Jung et al. (2015) reported an intervention that included education regarding fall prevention, neuro-developmental treatment (NDT), strengthening, balance, and flexibility training. Both studies reported a significant improvement among the treatment groups compared to the control as measured by the fall efficacy scale. However, the study by Batchelor et al. (2012) reported that their intervention did not reduce the fall rate among participants [16], while Jung et al. (2015) did not report on the fall rate [20].

Educational programs

One study reported using an educational program to reduce the risk of falls [30]. The program consisted of problem-solving sessions, action planning activities, fall prevention strategies, and home exercises. However, the authors reported that the risk of falls did not change after the educational program.

Multifaceted stroke telerehabilitation

Chumbler et al. (2015) reported using an intervention that included home visits (3 times), telephone calls (5 times), and a home messaging device provided over three months. The home messaging device instructed patients in functional exercises and adaptive strategies [17]. The authors concluded no differences in outcome between intervention and control groups as assessed by the fall efficacy scale.

Virtual reality

One study reported using a virtual reality rehabilitation program [31]. The program consisted of trunk mobilizations, stretching the arms and legs, and 45 minutes of Nintendo Wii exercises. The Nintendo Wii exercise games were performed in bouts of 12 minutes, with 1 min interval between two games. Results showed that the number of falls was significantly lower after 20 sessions in the experimental group.

Vitamin D supplements

Sato et al. (2005) reported on the benefits of vitamin D supplements for reducing falls [32]. Authors found that the use of low-dose vitamin D (1000 IU ergocalciferol) daily led to a decrease in the occurrences of falls compared to placebo.

Rehabilitation instruments

Four studies reported the benefits of using rehabilitation instruments to reduce falls [21, 26, 33, 34]. Rehabilitation instruments included whole-body vibration with a frequency range of 20-30 Hz, over-ground robotic walking training performed with the servo-assistive robotic rollator (i-Walker), ankle-foot orthoses (AFO), and local vibration applied to the plantar region with a frequency of 80 Hz for

10 seconds and 5 seconds rest. The whole-body vibration had no significant effect on the incidence of falls [21]. For the i-Walker, the number of fallers decreased following the intervention but was not statically significant [33]. Using an AFO early post-stroke was found to increase the occurrence of falls [34] significantly. Lastly, local planter vibration showed a statistically significant decrease in fall risk [26].

Physical activities

Various physical activities were reported in 15 studies as interventions to prevent/reduce falls [18, 19, 22, 23, 25, 27-29, 35-41]. These interventions included body-weight distribution training, stability exercises, modified-trampoline training, perturbation-based balance training, functional exercises, pedalo training, Tai-Chi exercises, strength exercises, dynamic neuromuscular stabilization, and dual-task training. The reported findings varied among studies about fall prevention/reduction. At the same time, most studies reported changes that are significant for fall reduction following the intervention. A few studies found that some interventions (e.g., functional exercises [37] and perturbation-based training [28]) are not statistically significant in reducing falls.

DISCUSSION

This systematic review aimed to identify and appraise the literature on available interventions related to fall prevention for patients after stroke. Our comprehensive literature search and screening resulted in 26 randomized controlled studies meeting the inclusion criteria. The total number of participants was 1619, and eight different categories of interventions were identified. Fifteen studies reported physical activity as an intervention; four studies reported using rehabilitation instruments; two studies reported using a multifactorial fall prevention program; one study reported using vitamin-D supplements; one study used an educational program; one study used virtual reality; one study used a multifaceted stroke telerehabilitation program, and one study reported using TDCS.

The methodological quality varied among the included studies, with a score range between 6-10 out of 11. Four studies scored six points on the critical appraisal tool, showing a moderately high bias level. Nevertheless, it is challenging to reach the total score on the critical appraisal tool. In addition, it is challenging for studies to utilize an exercise intervention for blind participants and therapists during the study.

The outcome of the interventions identified in this review can be classified into three groups. Studies reported a significant positive outcome on fall prevention/reduction, studies that reported a positive but non-significant effect, and studies that reported a negative effect. Twelve studies reported a significant positive effect on reducing the number of falls/risk of falls or improving the fall efficacy scale [18, 20, 22-27, 31, 32, 35, 40]. Five studies reported a positive effect on reducing the number of falls, albeit the effect was not statistically significant [29, 33, 36, 39, 41]. Nine studies reported a negative effect on reducing falls or improvement on the fall efficacy scale [16, 17, 19, 21, 28, 30, 34, 37, 38].

Two studies in our review reported the multifactorial fall prevention program [16, 20]. However, the outcome of this therapeutic intervention was different between these two studies. Two reasons can partially explain the differences in results between these two studies. First, different exercises were utilized in each study, as one study used the OEP [16] and the other study used NDT [20]. Furthermore, in the study by Batchelor et al., [16] the outcome measures used were fall rate and the fall efficacy scale, while the study by Jung et al. [20] used only the fall efficacy scale. The therapeutic programs used in these studies probably significantly affected the fear of falling rather than the fall rate.

In the study by Nikamp et al. [34], the authors reported that using an AFO immediately after a stroke can increase the occurrence of falls. Further, when using an AFO is delayed to 8-weeks after stroke, there was no change in the number of falls. This finding goes against common beliefs among clinicians that an AFO can lead to positive changes in balance and thus reduce the risk of falls. Furthermore, these findings raise serious concerns about the prescription of AFO for people post-stroke. Future studies are warranted to examine the findings of this study.

Physical activity interventions that showed an improvement on the fall efficacy scale or in reducing the risk of falls were reported by five studies [18, 22, 23, 25, 27]. Different forms of physical activity were used in these studies. However, none of these studies used "number of falls" as their outcome measure. With the lack of the number of falls as an outcome measure, it cannot be recommended with certainty that the interventions used in these studies are useful for preventing/reducing falls. Perhaps the forms of physical activity used in these studies are useful for decreasing the risk of falls or fear of falling. However, further research is needed to examine these forms of physical activity while assessing the number of falls as a primary outcome measure to assess the efficacy in preventing and lessening falls among patients after stroke.

The most promising interventions in decreasing falls among patients after stroke are dual-task exercises with cognitive training [40] and symmetrical bodyweight distribution training [35]. Both interventions showed a significant decrease in fall numbers after six months of follow-up for participants. However, the sample size in both studies was small, threatening that their results may have been underpowered. Thus, it is challenging to generalize these findings among the large stroke population.

One study reported that vitamin-D (ergocalciferol) supplements significantly reduced the number of falls among individuals post-stroke [32]. In this study, the authors reported that taking vitamin-D supplements increased serum 1,25-[OH]2D concentration, which may have reduced the number of falls. However, it should be noted that the same research group has conducted a similar study following the first one. In the following study, the authors reported using alendronate drugs for osteoporosis to reduce the number of falls with significant findings [42]. However, the second study has since been

retracted by the journal's Editor-in-Chief due to ethical and methodological considerations. Thus, the previous finding should be considered with caution.

Andarde et al. [24] reported that the use of TDCS significantly reduced the number of falls following acute ischemic stroke. However, in this study, the findings were observed from relatively small sample size and among a specific population (acute ischemic stroke). One instrument intervention in the current review showed a significant reduction in fall risk and improved stability among participants. The local planter vibration reported by Onal et al. [26] showed promising results. Nonetheless, future research that employs a larger sample size and reports the number of falls is warranted to assess this intervention fully.

The findings of the current review corroborate previous systematic reviews on the intervention efficacy for preventing and/or reducing falls among patients after stroke [5, 8, 43]. The present systematic review – which includes eight studies published in 2019 and 2020 not previously included in previous reviews – indicates that no single intervention can be recommended to prevent and/or reduce the fall numbers among individuals post-stroke. Previous reviews focused on studies that reported the number of falls and excluded studies that reported other fall-related factors (such as the risk of fall and falls efficacy scale). However, we intended to provide a more comprehensive view of the literature in the current review. Nonetheless, despite including more studies, our findings were similar to previous systematic reviews.

Several limitations are noted in the current systematic review. First, various types of interventions have different intensities, durations, and follow-up periods. Further, falls are measured differently between studies, and the population types (stroke type and onset) were different. These variations render the review more comprehensive, but it makes comparisons between studies more challenging. In addition, the sample size is relatively small in most of the included studies. Lastly, not all the included studies provide information about the level of disability and the use of walking aids for participants.

CONCLUSION

In conclusion, no fall prevention intervention can be generalized to prevent falls among people post-stroke. Further studies involving large sample sizes and different fall outcomes, including the number of falls or the fall rate, are needed to make valuable recommendations for clinical practice.

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