

Exercises to escalate lower extremity muscle strength in stroke patients: a scoping review



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ABSTRACT

Introduction: Stroke sufferers with weakness and paralysis of the lower extremities are at risk of experiencing balance disorders. It causes the risk of falling for stroke sufferers. The effects of falls can result in physical injuries such as bruises, abrasions, lacerations, and even fractures, head injuries, and bleeding. The effects of falling cause physical injury and increase the longer treatment time, so that it adds to the burden on the patient and family to pay for patient care. This literature review aims to identify the types of interventions that can increase the strength of the muscle lower extremity to prevent falls in stroke sufferers.

Method: This study used JBI Scoping Review Method (*Joanna Briggs Institute*) from 2 database sources: *Pubmed* and *Ebscohost*. Publication 2015-2021. Keywords to search are stroke, fall risk, intervention, body balance, muscle strength.

Results: There were 1,446 articles found, and six articles were worthy of review. The interventions used are training motor imagery (MI) using structured, progressive circuit class therapy (SPCCT), taping techniques from gluteal taping and hip abductor taping using elastic bands, rehabilitation programs wearing regent suits (RS) based on electromyography (EMG), low-intensity mobility training, perturbation-based balance training (PBT) and a combined assessment of the weight-bearing ratio and the four square step test. The combination of MI with structured, SPCCT provides a greater therapeutic effect on gait and leg muscle strength in stroke patients. Gluteal taping and hip abductor taping techniques using elastic bands improve functional performance in individuals with chronic stroke. A rehabilitation program that wears an RS and EMG were more effective than usual treatment in increasing the EMG pattern during movement and activities of daily living. A PBT can help prevent falls in everyday life after stroke, and the weight-bearing ratio and four square step tests can predict falls in stroke patients more precisely than the berg balance scale.

Conclusion: In conclusion, the exercises, techniques and programs performed can increase lower extremity muscle strength, improve walking balance and reduce the risk of falls in stroke patients. These interventions require different times and tools according to the training carried out.

Keywords: stroke, risk of falling, intervention, body balance, muscle strength

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INTRODUCTION

Stroke is an emergency condition in which a neurological deficit occurs due to a sudden decrease in blood flow to a localized area of the brain.¹ Stroke can also occur due to impaired blood circulation in the brain. Hence, it can lead a brain tissue death which can cause the patient to experience paralysis or death.² According to the World Health Organization (WHO), stroke is a disease that affects the human nervous system accompanied by clinical symptoms that develop very quickly in the form of focal and global neurological deficits. Stroke can last for 24 hours or more.³

Based on data from the World Health Organization (2016), the prevalence of stroke patients is the second leading cause of death after ischemic heart disease. Approximately 15 million people experience a stroke every year, and 5 million of them die, while 5 million others experience permanent disability.⁴ Most stroke patients are women, with a prevalence of 3.8 million people, while the rest, with approximately 3 million people, are men.⁵

The number of stroke sufferers in Indonesia in 2018 was around 10.9%, with the highest number occupied by the Province of East Kalimantan (14.7%)

and the lowest in the Province of East Kalimantan. Papua (4.1%). Furthermore, North Sulawesi Province ranks third highest after East Kalimantan. Meanwhile, the Special Region of Yogyakarta has a prevalence of stroke sufferers as much as 14.2%.⁶

Stroke has an impact on a decrease in productivity because patients will experience long-term disability sensory disorders such as decreased muscle strength and decreased body coordination abilities so that patients will become less productive.⁵ The existence of coordination disorders and balance disorders in stroke patients will reduce the ability to perform

individual functional activities.⁷

The prevalence of stroke patients who experience balance disorders or decreased coordination is 70-80%.⁸ The presence of balance disorders will cause post-stroke patients to be at risk for falling events.⁹ A fall is an event when a person falls to the floor with or without being witnessed by others, which occurs accidentally/unplanned, with or without causing injury.¹⁰ Based on research conducted by Persson et al. (2018), from 504 samples of stroke patients studied, 65 patients (13%) had experienced a fall at least once.¹¹ In a study conducted by Beghi et al. (2018), from 299 patients which have been sampled, 122 patients (47.1%) fell at least once during treatment; 82 patients (31.7%) experienced recurrent falls and 16%, 32%, and 40% fell at 2, 4, and 6 months.¹²

Several causes of falls in stroke patients have been reported. One of the most common causes of falls is loss of balance when walking indoors, especially on the toilet. After a fall, 34.1% of the individuals who fell could not stand independently. This fall incident not only causes physical injury but can also increase the length of treatment time, thereby increasing the burden on patients and families to pay for patient care. As a result of the physical injury experienced, it can cause bruises (*vulnus contusum*), abrasions (*vulnus excoriasi*), torn wounds (*vulnus laceratum*), and even more severe cases such as fractures, head injuries and bleeding.¹³ Around 180 stroke patients experienced a fall when the patient used a wheelchair, and as a result, 22% of them suffered injuries. Injuries from falls can include abrasions and contusions. Most of the injuries occurred in the upper extremities as much as 30.8% and the lower extremities with 25.6%. Patients who have fallen will usually have a decreased number of Berg Balance Scale (BBS) scores. Based on the previous research, there were 50% of patients reached less than 30 ($p < 0.01$) of their BBS score.⁵

One of the effects of stroke is a decrease in muscle function in the lower extremities, which results in a decreased ability to support, hold, and balance body mass and difficulty starting, directing, measuring the speed of the muscle's ability to maintain body balance, so stroke

patients can fall when starting a movement standing and walking. The interventions that can be done to avoid the risk of falling due to decreased muscle strength and balance disorders in stroke patients are a range of motion. Range of motion exercises can increase blood circulation to the extremities to prevent muscle atrophy, reduce vascular paralysis, provide a sense of comfort, and avoid complications due to lack of movements such as contractures and joint stiffness in post-stroke patients. According to Pongantung (2018), there were two people (13.3%) with a moderate risk of falling and 13 people (86.7%) with a high risk of falling. Walking balance after being given ROM in the lower extremities, two people (13.3%) with low fall risk, nine people (60%) with moderate fall risk and four people (26.7%) with high fall risk. It showed that the walking balance in stroke patients after doing a range of motion exercises on average had increased, with eleven respondents whose walking balance had changed.¹⁴

According to Maun et al. (2020), in their research on reducing the risk of falling in stroke patients by doing balance exercises on the parallel bar, it has been known that after experiencing a stroke, the patients who participated in the exercise 5 times within two weeks to train balance on the parallel bar had shown several results: 38.2% of stroke patients with a high risk of falling before being given exercise, experienced a decrease in the percentage of respondents to 23.5% after being given exercise. Besides, 32.4% of respondents with a low risk of falling experienced an increased risk after exercising to 47.1%.⁵ According to our explanation this article aims to identify the types of interventions that can increase the strength of the muscle's lower extremity to prevent falls in stroke sufferers.

METHODS

Literature Searching

This research is a scoping review using search techniques using a systematic approach and selection process. The databases used as sources for international libraries are PubMed and EbscoHost. These two databases are considered representative of the purpose of this study only to see what interventions are most

meaningful in increasing lower extremity muscle strength in patients with stroke. Furthermore, the inclusion criteria which were used are as follows: The sample of the study was patients with ischemic stroke and hemorrhagic stroke; The article should relate to interventions to increase muscle strength in the lower extremities in the prevention of falls in stroke patients; the article uses Randomized controlled trial design; articles published in the last five years, starting from 2015 to 2020; the article is not a research protocol; the article uses English, full text; the location of the study was stroke patients who were treated at the hospital

All relevant articles are screened and analyzed for inclusion or exclusion from the literature review based on quality and relevance to the review topic, questions, and objectives of the Scope review. To organize articles, an initial search of databases and journals by entering keywords; stroke, risk of falling, intervention, body balance, muscle strength

Data Collection

The initial search resulted in 1,446 articles relevant to the topics reviewed between 2015 and 2020. After duplicating 96 articles, 96 articles were screened based on title, and 1,315 articles were released. The remaining 35 articles were screened again based on abstracts, and 19 were excluded. The remaining 16 articles were entered into the next stage, namely full-text review and eligibility based on the inclusion and exclusion criteria set by the researcher. The results of the review of 16 articles, 10 articles were issued again because the research location, research design and intervention provided were not in accordance with the research objectives, so the remaining 6 articles were reviewed for quality and would be synthesized by the researcher in the final literature review report (Figure 1).

After we selected and extracted data for each article that had been obtained, detailed descriptions related to the name of the researcher, year of publication, setting, research design, respondent characteristics, type of intervention, duration of intervention and outcome measurement were summarized in the Table 1 below.

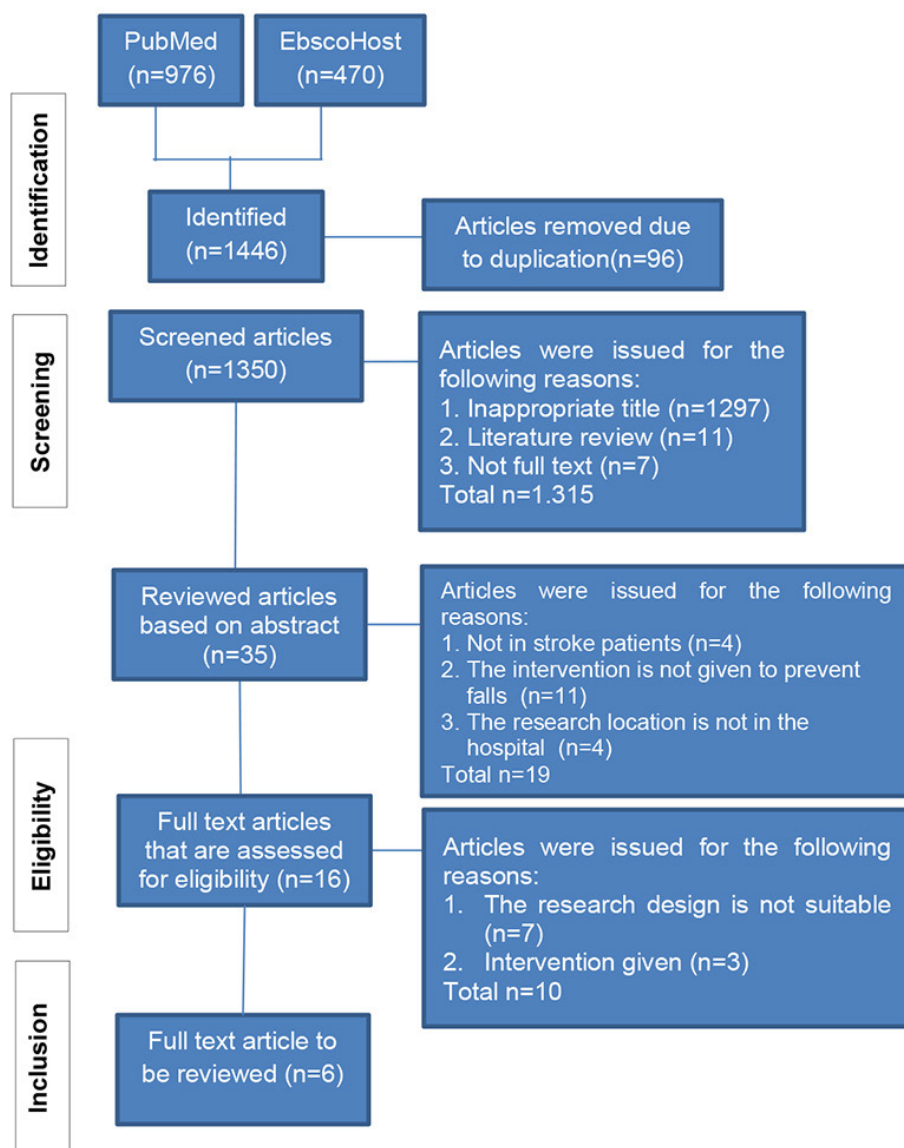


Figure 1. PRISMA Diagram

DISCUSSION

Stroke patients often experience long-term complications after rehabilitation. One of the most common complications is falls.²¹ The decreased neuromotor performance caused by the underlying disease resulting in stroke contributes to most falls in stroke survivors. Muscle weakness, impaired balance, loss of sensation, and limited mobility after stroke increase the likelihood of falling.²²

Falls result in further complications for stroke survivors, which place a psychological and economic burden on patients and families. Preventing falls in stroke survivors has been developed and

the results published. Interventions aimed at preventing falls in stroke survivors in the literature to date include assistive devices, post-intensive inpatient therapy through home visits, brain stimulation, and targeted exercise.²³

Preventing falls both in the hospital and at home for stroke survivors begins early in hospitalization with nurses and other healthcare team members and involves many different interventions. A review article reported that muscle weakness is one of the factors causing falls; therefore, it is considered the main goal to improve mobility ability in stroke survivors.²⁴

One of the interventions that can be done to prevent falls in stroke patients

is to train lower extremity muscle strength by doing several exercises such as motor imagery (MI) exercises and structured, progressive circuit class therapy (SPCCT). This study's result is in accordance with the results of Kumar's research (2016) that MI training with SPCCT gave significant results in all lower leg muscles on the affected side in the experimental group.²⁵ This intervention has the disadvantage of being limited by the retention effect of a training program that does not investigate an increase in gait performance but considers an increase in physical performance without an effect on neuroplasticity.¹⁵

Motor imagery (MI) is a cognitive functioning paradigm that involves mental imitation of movement without actual action. MI has been used as part of a training program in several clinical conditions to improve motor skills and has been shown to produce brain activity similar to real movement actions.¹⁵ MI is a way to train motor functions by involving sensory and cognitive functions. MI can help provide interventions that lead to brain recovery. This intervention has several advantages. For instance, it has a safe operation, inexpensive cost and has no side effects of fatigue during the intervention. The MI has effectiveness on post-stroke patients' cognitive, sensory and motor skills by stimulating neuroplasticity in various brain areas, thereby facilitating the increase in O₂, glucose and various metabolites that lead to an increase in regional metabolism through dilatation cerebral arterioles and capillaries. Motor Imagery (MI) given regularly will help restore the motor function in post-stroke patients and increase patient independence. Therefore, it can be concluded that MI has much effectiveness in rehabilitation post-stroke patients.²⁶

Circuit Class Therapy (CCT) is a form of task-specific training (TST) that involves structuring tasks on a circuit or series of workstations. It fulfills three main characteristics of an effective and efficient skills training program, including (1) using different workstations that allow people to train intensively in a meaningful and progressive manner according to their individual needs; (2) efficient use of

therapists/trainees/time; and (3) includes group dynamics such as peer support and social support.²⁷ The key components of this method are providing group therapy with a minimum of 2 participants under one therapist supervisor and encouraging repeated practice exercises with continuous development. It has advantages over other techniques and has been shown to increase therapeutic doses and reduce treatment costs.¹⁵ A study related to task-specific training, in the form of gradual ROM exercises combined with surrender exercises, was proven to significantly increase the voluntary muscle strength of patients with stroke.²⁸

Balance disorders are one of the problems often found in post-stroke patients. Interventions that can be done to prevent balance disorders in stroke patients are to use the gluteal and abductor taping technique using non-elastic bands. Four assessments were used to evaluate the effectiveness of this technique: (1) using the berg balance scale (BBS) to assess participants' balance; (2) assessing walking speed using an optogait system; (3) using a 6-minute walk test (6MWT) to evaluate walking endurance, and (4) the Falls Efficacy Scale (FES) was used to measure fear of falling. This study concluded that participants who received the gluteal and abductor taping intervention showed improvement in walking balance.¹⁶

Non-elastic bands are often used to improve joint alignment and increase muscle activity to generate musculoskeletal forces.²⁹ The taping technique strengthens weakened muscles, regulates joint instability, postural aid alignment, reduces pain, increases blood flow and lymphatic circulation, relieves flexibility, and strengthens muscle function.³⁰ The results of this study are supported by Shin et al. (2017), where the results of their research show that walking function in chronic stroke patients improves after posterior pelvic tilt taping. These results support the hypothesis that the posterior pelvic tilt taping method decreases excessive pelvic anterior tilting and affects gait in patients with chronic stroke. Gait velocity, step length, and stride length improved significantly with posterior pelvic tilt taping compared to placebo and no taping.³¹ The limitation in

this study is the lack of long-term effects of the intervention; future studies should evaluate the long-term effects of using this gluteal taping.¹⁶

In their research, DeMark et al (2019) conducted backward walking (BW) training to determine balance, walking ability, and risk of falling in stroke patients. Balance disorders are one of the problems often found in post-stroke patients; balance disorders will cause post-stroke patients to experience disturbances in carrying out daily activities and increase the risk of falling.⁹ Backward walking (BW) is an intervention that can improve balance and self-efficacy in improving mobility function after stroke. It has been used in orthopedic rehabilitation because it produces less mechanical strain on the knee joint while running backward; it effectively increases quadriceps strength. Walking backward improves gait and dynamic balance post-stroke. Post-stroke individuals fall during walking forward and when turning or moving, both of which often require a backward step. The benefit of the Backward walking (BW) exercise is that it challenges the postural stability required for such tasks. A second benefit is that it engages brain pathways damaged by stroke, potentially enhancing neuroplastic recovery. Compared to walking forward, walking backward was more effective in inducing brain activation. A third benefit is that walking backward allows patients to practice coordinated movements independent of the abnormal compensatory movement patterns characteristic of walking forward after stroke.³²

Another intervention was carried out by Mansfield et al. (2018). In their research on Perturbation-based balance training (PBT), it was found that PBT was the only intervention with the capacity to improve reactive balance control. PBT can be a useful adjunct to balance training and long-term fall prevention in stroke survivors. A balance training program usually includes exercises that aim to improve the ability to maintain balance while remaining still or during movement. This type of balance training can prevent falls by reducing the risk of losing balance in daily life, but the occasional loss of balance may be an unavoidable consequence of mobility, as

can the ability to react quickly after losing balance. Perturbation-based balance training (PBT) can improve post-stroke reactive balance control. Another previous study found that those who completed PBT during inpatient stroke rehabilitation fell less frequently after discharge than those who did not complete PBT.¹⁹

Based on the research of Iuppariello et (2018) regarding the benefits of rehabilitation using electromyography (EMG)-based regent suite (RS), it was found that treatment with a regent suite (RS) was more effective than usual care in improving EMG patterns during movement and activities of daily living in chronic post-stroke patients. The RS is a special device that takes inspiration from experimental models used to counter the negative effects of the absence of gravity caused by the nervous system of astronauts during their spaceflight. The therapeutic effect of RS is based on the induction of a pre-measured amount of afferent proprioceptive flow.¹⁸ Walking exercises that can create measurable afferent proprioceptive flow can be performed by wearing a suit based on elastic elements, called a regent suit.³³

The basic principle of a regent suite (RS) is the ability to produce a "controlled effect" on a specific muscle group using elastic loading elements (ELE) and recoil lifting weights attached to a support structure. The muscles that receive the load send signals to the cerebrum, giving them a response command to contract or relax. Thus, according to the Proprio dynamic correction principle, the nerve ties lost due to stroke will be restored or re-formed.¹⁸

The main problem that will arise in stroke patients is the damage/death of brain tissue which can cause a decrease or even loss of function controlled by the network. One of the symptoms caused is a disability in the form of paralysis of the hemiparesis limb or muscle weakness in the affected limb, such as the fingers. The function of the extremities is pivotal in carrying out daily activities and is the most active part.³³ Therefore, if there is weakness in the extremities, it will greatly hamper and interfere with daily abilities and activities.

Low-intensity mobility training improves muscle strength, balance

and walking speed in stroke patients. According to a study on the low-intensity experimental group (LI-E) and high-intensity active control group (HI-C) who received the endurance phase and the mixed-phase for 8 weeks, it was concluded that there was more increase in muscle strength, walking speed, and balance in the low-intensity experimental group (LI-E) than in the high-intensity active control group (HI-C).²⁰

One of the causes of falls in stroke patients is loss of muscle strength.³⁴ Muscle strength is the ability of muscles to withstand loads in external and internal loads.³⁵ Decreased ability to move muscles in a patient's limbs who have had a stroke is due to experiencing weakness on one side of the body.³⁶ Meanwhile, reduced muscle contraction is caused by the reduced blood supply to the hindbrain and midbrain, which can inhibit the conduction of the main pathways between the brain and spinal cord.³⁷ This research has limitations, such as only using two databases so that the articles obtained are also still lacking.

CONCLUSION

In conclusion, the exercises, techniques and programs performed can increase lower extremity muscle strength, improve walking balance and reduce the risk of falls in stroke patients. The implication of this research is to initiate a rehabilitation center in carrying out treatment to increase the strength of the weak lower extremity muscles in patients with stroke. It is also useful for further research to be developed through meta-analysis research.

DISCLOSURE

Conflict of Interest

There is no conflict of interest between the authors

Ethics Approval

not applicable

Author Contribution

According to this article AM was searching articles, critical appraisal, drafting reports, eman while NC was re-checking the writings that have been made, conducting analysis studies and compiling publications.

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Table 1. List of synthesized articles

No	Author(s) name & publication year	Country	Research design	Characteristics of respondents	Type of intervention	Intervention duration and the tools	Outcome measurement
1	Bovonsunthonchai et al., 2020	Myanmar	RCT	40 stroke patients were sampled with ages 18 - 75 years	Training with Motor Imagery (MI) using Structured Progressive Circuit Class Therapy (SPCCT)	The experimental group received 25 minutes of Motor Imagery (MI) training preceded by 65 minutes of SPCCT, while the control group received 25 minutes of Health Education (HE) using a pamphlet followed by 65 minutes of SPCCT program with an overall intervention time of 90 minutes. Both groups received training 3 times a week for 4 weeks.	Temporo-spatial gait variables and lower extremity muscle strength on the affected side were assessed at baseline, 2 weeks, and 4 weeks after the intervention. After 4 weeks of training, the experimental group showed greater improvement than the control group in all temporospatial gait variables, except for unaffected stride length and stride time symmetry which showed no difference. In addition, greater improvements in the strength of the affected hip flexor and knee extensor muscles were found in the experimental group. In conclusion, the combination of MI with SPCCT provides a greater therapeutic effect on gait and lower leg muscle strength in stroke patients. ¹⁵
2	Chen et al., 2019	Tiongkok	RCT	28 people with stroke were sampled with ages 58 – 59 years	Gluteal band and hip abductor band technique	The duration of the recording intervention was approximately 30 minutes, using a non-elastic gluteal band and a hypoallergenic band	Based on in-group analysis, it could be concluded that non-elastic hip gluing significantly increased BBS ($\rho = 0.004$), walking speed ($\rho = 0.049$), and 6MWT ($\rho = 0.001$). This study showed that hip extensors and abductor taping immediately improved balance and walking in a cane-dependent ambulator. Current research proves that hip taping is a therapeutic strategy to improve functional performance in individuals with chronic stroke. ¹⁶

No	Author(s) name & publication year	Country	Research design	Characteristics of respondents	Type of intervention	Intervention duration and the tools	Outcome measurement
3	DeMark et al.,2019	Amerika Serikat	RCT	8 people with stroke who were sampled aged 47-81 years	Backward walking training	Backward walking (BW) training was given 20 minutes after participants completed 3 hours of standard therapy each day. The training was conducted in 10 sessions	All eight patients showed improvement in all outcomes with clinically significant improvement in forward walking speed, as measured by the 10 Meter Walk Test (MWT) without serious side effects. The improvement in balance was evidenced by improvements in the berg balance score (BBS) (17.1 ± 11.4 to 47.1 ± 8.1. Five of the eight participants exceeded the fall risk limit score of <60%.
							Improvements in walking function were the eventual evident based on increased forward and reverse walking speed and reduced Timed Up and Go Test (TUG) times. The mean forward walking speed increased from 0.24 ± 0.15 to 0.90 ± 0.15 m/s from admission to post-intervention, and eight participants exceeded the minimal clinically important differences (MCID) of 0.16 m/s for the acute stroke patient population. ¹⁷
4	Iuppariello et al.,2018	Italia	RCT	In this study, 20 healthy controls (age 43 ± 8 years old, 15 males, 5 females) and forty patients with residual hemiparesis due to ischemic or hemorrhagic stroke (age 45 ± 10 years old, 30 males, 10 females); 25 (62.5%) were ischemic, 15 hemorrhagic	Rehabilitation program using Regent Suite (RS) based on Electromyography (EMG)	Each pathological subject received individual rehabilitation training of 40 minutes per session and was carried out for 5 days a week, including traditional neuromotor techniques, articular mobilization, stretching exercises, "sitting to standing" exercises, step decomposition exercises.	The proprioceptive stimulation of RS-based treatment induced a higher and remarkable recovery from normal muscle activation times also improved muscle symmetry and reduced pathological muscle coactivation on the affected and unaffected sides.
							Conclusion: These results confirm that hospital-based care was more effective than usual care in improving EMG patterns during movement and activities of daily living in chronic post-stroke subjects. ¹⁸

No	Author(s) name & publication year	Country	Research design	Characteristics of respondents	Type of intervention	Intervention duration and the tools	Outcome measurement
5	Mansfield et al., 2018	Kanada	RCT	There were 42 control participants and 41 PBT participants, with a median age of 66 - 67 years	<i>Perturbation-based balance training (PBT)</i>	Participants undertake two 1 hour training sessions per week for 6 weeks and two 1 hour 'reinforcement' training sessions for 3 - 9 months after the initial training period. Participants wear special safety straps attached to overhead support during the training process to prevent falling when receiving external interference.	The PBT participants reported 32 falls (1.07 falls/person-year), and the control participants reported 57 falls (1.75 falls/person-year). PBT participants experienced greater improvement in reactive balance control than the control group, and this improvement was maintained 12 months after training, so it can be concluded that PBT may help prevent falls in post-stroke daily life, but continued training may be required to maintain its benefits. ¹⁹
6	Lamberti et al., 2017	Italia	<i>Pilot Randomized Controlled Study</i>	Thirty-five chronic stroke patients (mean age: 68.4 ± 10.4 years)	Low-Intensity Training	The intervention lasted 8 consecutive weeks and consisted of 24 supervised training sessions of approximately 1 hour each (3 sessions/week). The 8-week program is divided into an endurance phase based on walking exercises (weeks 1-4) followed by a mixed-phase (weeks 5-8). The experimental group (LI-E) used a linear encoder with weights attached to the ankles, while the control group (HI-C) used a treadmill gym machine (leg extension and leg curl).	After 8 weeks, 6-Minute Walking Distance (6MWD) revealed more improvement for the low-intensity group (LI-E) than the High-intensity (HI-C) group = 0.009. The physical activity domain of SF36 ($\rho = 0.012$) and peak strength of the quadriceps and femoral biceps were also significantly increased for the LI-E group ($\rho = 0.008$ and $P < 0.001$, respectively) compared to the HI-C. Low-intensity exercise programs showed better mobility, quality of life, and muscle strength than high-intensity programs. ²⁰