

## REVIEW ARTICLE

# Effectiveness of various lower extremity rehabilitation techniques to improve quality of life in post-stroke patients

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## ABSTRACT

The ability to move the lower extremities in individuals who have suffered from a stroke presents significant challenges to daily mobility and function. We conducted a systematic evaluation to compare the effectiveness of physical rehabilitation following a stroke. We searched six databases (PubMed, Science Direct, Cochrane Library, Springer, Portal Garuda, and Nature Portfolio) for publications published before November 2023. The researchers recruited stroke patients and used a validated scale to assess lower extremity strength and walking capacity in post-stroke patients. We used the Joanna Briggs Institute Critical Appraisal Checklist to evaluate the quality of the papers that met the inclusion criteria. The PRISMA checklist was used to report the study. We identified nine relevant articles that discussed various rehabilitation methods for stroke patients with lower extremity impairment. We examined the specificity of these results using a statistical parameter. The findings were as follow: Biofeedback cycling ( $P < 0.001$ ); Pelvic Stability Training ( $P < 0.05$ ); Exoskeleton for post-stroke recovery of ambulation (ExStRA) ( $P < 0.05$ ); Aerobic Cycling ( $P < 0.001$ ); Somatosensory Training ( $P < 0.001$ ), Lower-extremity constraint-induced movement therapy ( $P < 0.001$ ), Motor imagery with circuit class therapy ( $P < 0.001$ ), Robotic gait training ( $P < 0.05$ ), and Early and Intensive Rehabilitation ( $P < 0.001$ ). Various rehabilitation methods discussed in the article demonstrate high effectiveness in improving lower extremity function. These methods include biofeedback cycling, aerobic cycling, somatosensory training, movement therapy, motor imagery combined with structured progressive circuit therapy classes, and early and intensive rehabilitation after ischemic stroke.

**Keyword:** Effectiveness, Lower Extremity, Movement, Post-Stroke, Quality of Life, Rehabilitation.

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## INTRODUCTION

Stroke is an acute and focal neurological impairment caused by vascular injury (infarction, haemorrhage) in the central nervous system lasting longer than 24 hours.<sup>1</sup> A stroke is a brain disorder that occurs when blood flow to a specific area of the brain is blocked.<sup>2</sup> Blockages in the delivery of blood and oxygen can cause the nervous system to stop working and potentially leading to death.<sup>3,4</sup> The movement of nervous system organs may become impaired.<sup>5</sup> Stroke is the second leading cause of death and the third most common cause of disability.<sup>6,7</sup> Stroke risk factors are similar to those associated with coronary heart disease and other vascular disorders, including smoking and a lack of exercise, poor eating habits, and obesity.<sup>8,9</sup> Research indicates that men tend to experience strokes at a younger age compared to women.<sup>10</sup> In women, the hormone estradiol has a dilatatory solid effect on the vascular endothelium, promoting increased blood flow.<sup>11,12</sup> In contrast, testosterone in men has a reverse impact, leading to an endothelial constriction and reduced blood flow.<sup>13,14</sup> This difference contributes to a higher risk of stroke in men compared to women. In addition, men also have other risk factors, such as smoking and alcohol consumption. In 2013, Riskesdas reported a nationwide stroke prevalence of 10.9 per mile, but in 2018, the prevalence decreased to 7 per mile. East Kalimantan Province exhibited the most extensive distribution (14.7 per mile), while Papua Province had the lowest (4.1 per mile).<sup>15</sup>

A stroke can lead to strength deficiencies, sensory-motor problems, spasticity, incoordination, and postural dysfunction.<sup>16</sup> Stroke can cause impaired motor control and limb weakness, reducing muscle strength and affecting the coordination of functional movements, particularly in the lower extremities.<sup>17</sup> Several studies have mentioned that disturbances are more pronounced in the

upper extremities compared to the lower extremities. Additionally, the same survey demonstrated that the recovery of the upper and lower extremities follows a parallel timeline, with the recovery of lower extremities being highly dependent on the initial level of disturbance.<sup>18,19</sup> Lower limbs may recover motor function more quickly than upper limbs following a stroke.<sup>20</sup> Although there are numerous aspects that can assist explain the causes, the most essential one is the intensity, frequency, or dosage of the lower limb usage compared to upper limb usage, as well as the presence of spasticity and its major impact on the upper limbs.<sup>20,21</sup>

Post-stroke patients often experience a 34% to 62% reduction in muscle strength in their lower extremities.<sup>22</sup> The inability to walk affects more than 80% of individuals who have suffered from a stroke.<sup>23,24</sup> It is estimated that approximately one-quarter of all stroke patients cannot walk without assistance three months after the stroke.<sup>25</sup> Furthermore, it cannot be denied that decrease in walking speed in post-stroke patients is a predictor of all-cause mortality and associated with lower survival rates, increased risk of falls, and reduced quality of a life.<sup>26,27</sup> This situation is also a burden for the productive age group responsible for caring for post-stroke individuals with disability.<sup>28</sup> Post-stroke patients need a caregiver or nurse to assist with their daily needs and activities.<sup>29</sup> Stroke is a catastrophic disease associated with significant cost, volume, and risk. It leads to increased medical expenses and the need for special treatment.<sup>30,31</sup> Caring for post-stroke patients with disabilities poses challenges due to both physical and psychological burden experienced by their families.<sup>5,32</sup> To address this gap, this systematic review aims to evaluate the most effective rehabilitation strategies for improving walking ability and lower extremity strength following a stroke. The synthesis of this evidence will have many implications for stroke survivors and their families.

## METHODS AND SUBJECT

Data were collected from articles published in six databases (PubMed, ScienceDirect, Cochrane Library, Springer, Garuda Portal, and Nature Portfolio) using keywords related to "stroke" and "lower extremity abilities" in the titles and abstracts of studies published from the baseline data through November 2023. Two reviewers independently examined each article's title and abstract before reviewing the full text for potentially relevant studies. Any disagreements regarding selection were resolved through consultation with the senior author. We employed the Joanna Briggs Institute Critical Appraisal Checklist to

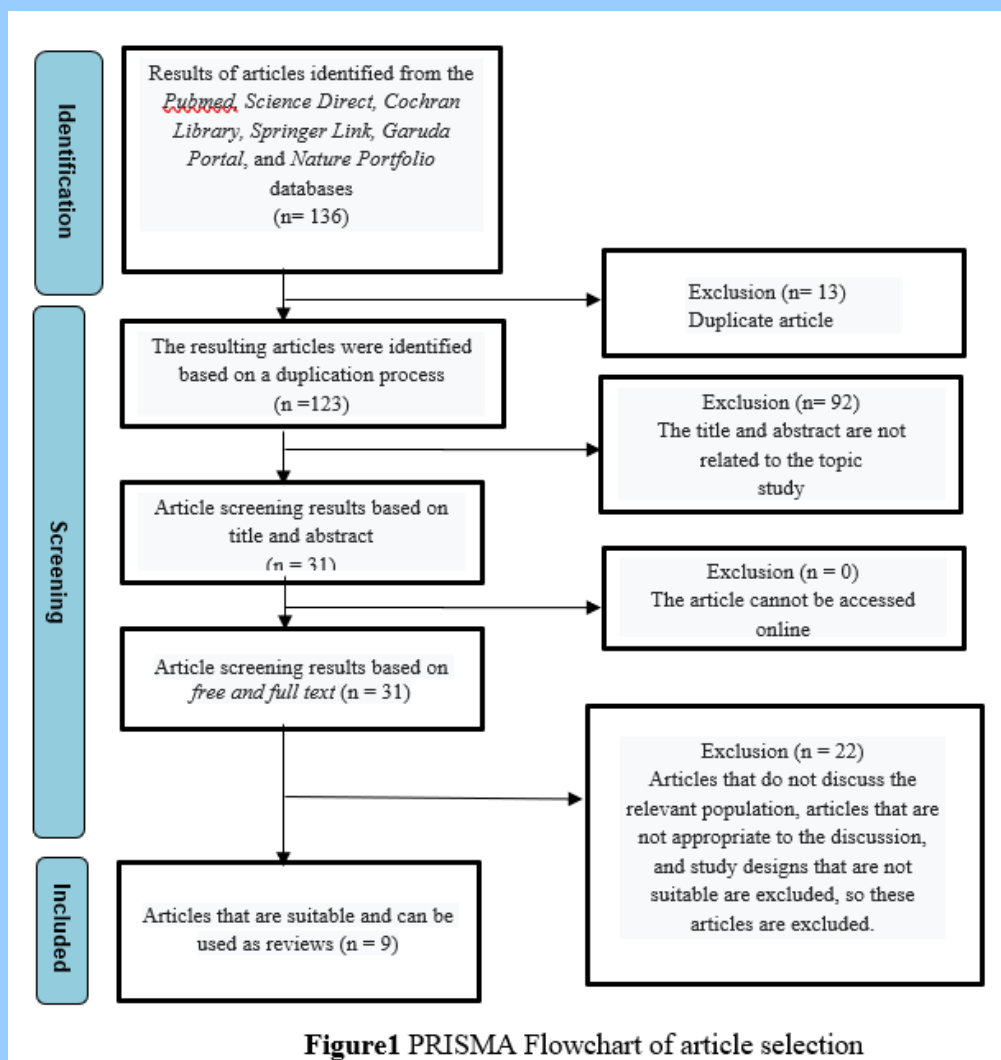
assess the quality of the research that met the inclusion criteria. The following inclusion criteria were applied: 1) studies published within the last decade (2013-2023); 2) studies available in Indonesian and English; 3) publications that meet the quality assessment standard of the the Joanna Briggs Institute Critical Appraisal Checklist; and 4) studies with free and full-text access. A total of 136 papers was collected, sourced from 5 in PubMed, 102 in ScienceDirect, 11 in Cochrane Libraries, 6 in Springer, 8 in Garuda Portals, and 4 in Nature Portfolios. All research is available on Mendeley. Table 1 shows the total number of items found in Database 4.

**Table 1** Article identification results

Database	Boolean Operator	Number of Articles
PubMed	((("Post-stroke patient" OR "After stroke")) AND ((("Physical therapy" OR "movement training" OR "Physiotherapy" OR "Physical training")) AND ((("lower extremity movement" OR "movement recovery" OR "movement ability"))))	5
Science Direct	((("Post-stroke patient" OR "After stroke")) AND ((("Physical therapy" OR "movement training" OR "rehabilitation" OR "Physical training")) AND ((("lower extremity movement" OR "movement recovery" OR "lower extremity function"))))	102
Cochrane Library	"Physical therapy" OR "movement training" OR "Physiotherapy" OR "Physical training" in Title Abstract Keyword AND " Post-stroke patient " OR "After stroke" in Title Abstract Keyword AND " lower extremities " OR "lower limbs" OR "recovery" OR "movement" OR "lower extremities nerve" OR "walking"	11
Springer	"post-stroke" AND ("physical therapy" OR "rehabilitation" OR "physical treatment") AND "lower extremity"	6
Portal Garuda	("latihan berjalan" OR "terapi berjalan") AND ("pasca stroke")	8
Nature Portfolio	((("Post-stroke patient" OR "After stroke")) AND ((("Physical therapy" OR "movement training" OR "Physiotherapy" OR "Physical training")) AND ((("lower extremity movement" OR "movement recovery" OR "movement ability"))))	4
	<b>Result</b>	<b>136</b>

The journal selection process begins by referencing articles published up to 2013 and identifying duplicates. Next, the articles were selected based on their title, abstract, and full-text availability. The final step involves assessing eligibility according to established criteria. The results of the duplicate selection revealed that 13 articles were excluded. Additionally, the selection process based on titles and abstracts that were not relevant to the research topic led to the exclusion of 92

articles. The full-text selection process revealed that all articles were included because they were accessible in full text. The final stage involves assessing the article according to feasibility, sample size, and study design. A total of 22 articles were excluded, resulting in 9 articles deemed appropriate for the research topic used as materials for systematic review. The results and the article study selection process are illustrated in the flow diagram in Figure 1



Ethical approval was not required for this systematic review as there was no involvement of patient

## RESULTS AND DISCUSSION

Nine articles have undergone a systematic review based on a study selection process that utilized PICOS, along with specific inclusion and exclusion criteria. The review of article studies yielded mixed results regarding the effectiveness of physical rehabilitation for the lower extremities. The studies included a variety of research designs: Crossovers (one article), Randomized Controlled Trial (seven articles), and cohort (one article). The articles reviewed were published over the past ten years. The study was conducted in several countries, including China, India, Columbia, America, Saudi Arabia, Sweden, Myanmar, Korea, and Taiwan, with one article from each of these articles. Participants of the study consisted of post-stroke patients with limited mobility in the lower extremities. Rehabilitation intensity varied, including five sessions per week for four weeks, three sessions per week for more than six weeks, three sessions per week for eight weeks, three session per week for eight weeks, daily session per week for two weeks, three sessions per week for four weeks, five sessions in one week, and five sessions per week for four weeks, followed by additional four weeks. The characteristics of each study are summarized in Table 3.

This systematic study demonstrates that all stroke patients with reduced

mobility in their lower limbs require different techniques and durations to regain function. According to two articles, the outcomes of patients who received rehabilitation did not significantly impact their recovery. This finding contrasts with others, as some participants had diseases or comorbidities that may have influenced the study's outcomes.<sup>33</sup> In other articles, fewer significant results occurred due to a lack of participants and insufficient intensity and duration of the rehabilitation interventions. There were significant neuroplastic alterations.<sup>34</sup> Seven additional studies identified substantial differences in patients before and after rehabilitation. In cycling training, biofeedback enhances the activity of inhibitory monosynaptic corticospinal pathways while reducing stimulated monosynaptic connections between neurons and muscles. This response can help restore the balance between muscular activity and monosynaptic motoneurons.<sup>35</sup> The article Effects of Pelvic Stability discusses how Training in movement control shows that movement in the pelvis of post-stroke patients correlates with walking speed. An increase in pelvic stability demonstrates the benefits of training on balance and allows for greater control of stance and limb advancement, which are essential determinants of walking speed.<sup>36</sup>

**Table 2.** Characteristics of -each study

No	Article Title	Writer	Year	Study Design	Method	Results	Publisher
1	Effect of Biofeedback Cycling Training on Functional Recovery and Walking Ability of Lower Extremity in Patients with Stroke	HC, et al	2013	Crossovers	Stroke patients underwent conventional rehabilitation combined with cycling training (30 minutes per session, five sessions per week for four weeks), followed by an additional four weeks of conventional rehabilitation alone	The findings revealed that an additional biofeedback cycling training for four weeks significantly improved lower extremity function, walking endurance, and speed in patients with chronic stroke. ( <b>p &lt; 0.001</b> )	Elsevier Taiwan LLC
2	Effects of Pelvic Stability Training on Movement Control, Hip Muscle Strength, Walking Speed , and Daily Activities after Stroke	Lavnika Dubey, et al	2018	Randomized Controlled Trial	Stroke patients performed pelvic stability exercises, using verbal instructions.	Pelvic stability training is effective in improving trunk and lower extremity movement control, hip muscle strength, walking speed, and the ability to perform daily activities in stroke patients. The results revealed a threefold difference, with hip stability training showing the most significant benefit (77%) compared to conventional physiotherapy (23%). Hip stability improved significantly ( <b>p &lt; 0.05</b> ).	Annals of Neurosciences
3	Exoskeleton for Post-Stroke Recovery of Ambulation (ExStRA): Study Protocol for a Mixed-methods Study Investigating the Efficacy and Acceptability of an Exoskeleton-Based Physical Therapy Program During Stroke Inpatient Rehabilitation	Dennis R. Louie, et al	2020	Randomized Controlled Trial	Forty adults with subacute stroke undertook inpatient rehabilitation to get an exoskeleton-based gait rehabilitation programme.	This research has not shown significant improvement in walking ability or walking distance. ( <b>p &lt; 0.05</b> )	BMC Neurology

No	Article Title	Writer	Year	Study Design	Method	Results	Publisher
4	Forced and Voluntary Aerobic Cycling Interventions Improve Walking Capacity in Individuals with Chronic Stroke	Susan M, et al	2020	Randomized Controlled Trial	The patient performed one of the interventions, specifically using an aerobic bicycle, at an intensity of three times per week for a duration of eight weeks.	Cycling cadence, power output, and starting distance all significantly affected changes in walking capacity in this study.  <b>(p &lt; 0.001)</b>	American Congress of Rehabilitation Medicine
5	Impact of Somatosensory Training on Neural and Functional Recovery of Lower Extremity in Patients with Chronic Stroke	Reem M., et al	2021	Randomized Controlled Trial	Thirty male and female patients were randomized into two equal groups: the control group (GI) and the intervention group (GII).  Group (GI) received four components of a conventional physical therapy program in sequential order: cyclic training, progressive isotonic exercises, stretching exercises, and functional purpose sit-stand exercises.  Patients in group (GII) get underwent the same conventional physiotherapy program in the same order as group (GI), but for a total duration of 30 minutes, divided into components of 15, 10, 5, and 5 minutes components. Patients were also trained in thermal stimulation (TS), as well as tactile, visual, and auditory stimulation.	Current somatosensory approaches have used augmented thermal simulation by adding tactile stimulation, successfully improving the functional performance of lower extremities affected by stroke and brain nerve activity.  <b>(p &lt; 0.001)</b>	MDPI

No	Article Title	Writer	Year	Study Design	Method	Results	Publisher
6	Lower-Extremity Constraint-Induced Movement Therapy Improved Motor Function, Mobility, and Walking after Stroke	Ingela Marklund, et al	2023	Cohorts	Lower extremity constraint-induced movement treatment was administered to all patients for two weeks, at a rate of six hours per day.	High-intensity lower extremity constraint-induced movement therapy significantly improved motor function, functional mobility, and walking ability in middle-aged patients during the subacute and chronic post-stroke stages.  ( <b>p &lt; 0.001</b> )	European Journal of Physical and Rehabilitation Medicine
7	Motor Imagery Combined with Structured Progressive Circuit Class Therapy on Gait in Stroke Survivors	Sunee B, et al	2020	Randomized Controlled Trial		The combination of motor imaging imagery intervention and Structured Progressive Circuit Class Therapy (SPCCT) improves spatiotemporal gait variables and positively affects influences muscle strength when compared to Health Education (HE) and Structured Progressive Circuit Class Therapy (SPCCT) alone. According to the study, experts recommend that physiotherapists employ incorporate motor imaging imagery in conjunction alongside with exercise, rather than relying on exercise alone, in the treatment of stroke patients. ( <b>p &lt; 0.001</b> )	Nature Research: Scientific Reports

No	Article Title	Writer	Year	Study Design	Method	Results	Publisher
8	Neuroplastic Effects of Defector Robotic Gait Training for Hemiparetic Stroke	Hayeon Kim; Gyulee Park; JoonHo Shin, et al	2020	Randomized Controlled Trial	Thirty volunteer participants with hemiparetic stroke received similar treatment, specifically end-effector robot-assisted gait training.	End-effector robot-assisted gait training improves neuroplastic outcomes in hemiparetic stroke patients; however, its effectiveness compared to conventional training remains uncertain. ( $p < 0.05$ )	Nature Research: Scientific Reports
9	Effect of Early and Intensive Rehabilitation after Ischemic Stroke on Functional Recovery of the Lower Limbs	W-X Wu, MD, et al	2020	Randomized Controlled Trial	Thirty-one eligible patients underwent rehabilitation to enhance lower extremity mobility within 48 hours of experiencing a stroke.	Rehabilitation initiated within 48 hours post-stroke significantly contributes to the recovery of lower extremity function in patients with acute ischemic stroke. However, further research is necessary, as there remains a limited research in this area. ( $p < 0.001$ )	Journal of Stroke and Cerebrovascular Diseases

When a stroke occurs, cellular changes in skeletal muscle take place, including changes in the proportion of fiber types, loss of type I muscle fibers, atrophy, and decreased oxidative capacity. Physical activity and intense sports training have been shown to alleviate or reverse these conditions. This is further supported by research findings indicating that aerobic cycling interventions with moderate to high cadence, combined with strength training, result in the most significant improvement in walking capacity among post-stroke patients.<sup>37</sup> The research on the influence of somatosensory training indicates that transcallosal connections between homologous motor areas facilitates inter-hemispheric communication, potentially leading to a greater excitability.<sup>38</sup> This finding is also supported by studies showing that high-intensity training, particularly through the treadmill method can increase walking

ability, aligning with previous research.<sup>39</sup> Additionally, evidence also suggests that combining physical exercise with motor imagery (MI) can further increase the effectiveness of this therapeutic approach. Moreover, integrating exercise with structured progressive circuit class therapy (SPCCT) may result in even better outcomes, as revealed in one of the studies.<sup>40</sup> Movement and walking exercises for post-stroke patients have been described multiple times as being capable of improving the functional abilities of the lower extremities. Additionally, there is an ongoing discussion regarding the optimal time to start physical rehabilitation that is most effective for movement recovery, including research that reveals that brain plasticity decreases during the early stage of a stroke, suggesting that the most effective period for rehabilitations occurs shortly after the onset of the stroke.

Several studies involving animals have demonstrated that those who begin locomotor exercise rehabilitation 24 to 48 hours after a stroke exhibit better behavioral outcomes and reduced ischemic volumes compared to animals that start exercise training later or not at all.<sup>41</sup> However, there are several significant limitations in this research: 1) The data used in the research is difficult to obtain, 2) the high heterogeneity among participants complicates the determination of the most effective physical rehabilitation method, and 3) the duration of physical rehabilitation varies across studies, which may lead to different results.

## CONCLUSION

According to the findings of the study, rhythmic lower extremity movements performed at moderate to high intensity immediately after the onset of a stroke can significantly restore extremity function compared to other forms of physical rehabilitation. This type of lower extremity movement training also does not require complicated equipment, is relatively low-cost, and does not necessitate any specific skills to operate the equipment. However, it is essential to consider several health aspects, such as the patients' general condition, vital signs, and any comorbidities. Therefore, further research is needed to identify additional indications and contraindications for implementing physical rehabilitation in the future.

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## DECLARATION OF INTERESTS

The authors declare that they have no conflicts of interest.

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