# The Use of Treadmills to Improve Post-stroke Walking Patterns: A Literature Review

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**Abstract.** Walking is one of the most difficult issues for stroke patients. The ability to walk in stroke patients recovers at different rates due to variations in weakness and intervention, including treadmill intervention. Nobody has looked into how the treadmill affects the phases of a stroke patient's walking pattern until now. This study is designed to discover the various improvements in walking patterns that occur in post-stroke patients after a treadmill intervention. The study used data from PubMed, Cochrane, ResearchGate, and ScienceDirect over the last ten years. The article's inclusion criteria included published in English, articles with randomized controlled trials (RCTs), who had a stroke within the previous more than two months and had walking disorders, using a treadmill as an intervention, and published between 2012 and 2022. The keywords used are "treadmill," "gait pattern," and "stroke." The PICO (population or problem, intervention, comparison, outcome) framework was used to review this study. A total of 7 studies met the criteria for this review, with an average PEDro score of 6.71 and good quality. The use of a treadmill in post-stroke patients can improve walking speed, endurance, adaptability, and ability in the walking cycle of subacute and chronic stroke patients with a minimum dose of three times per week to do full treadmill exercise. Using a treadmill after a stroke can improve speed, endurance, and walking pattern ability.

**Keywords:** Stroke · Gait pattern · Treadmill

## 1 Introduction Section

A cardiovascular condition known as stroke affects the arteries leading to the brain. Strokes happen when the blood arteries that provide oxygen and nutrients to the brain become clogged by a clot or fragment, depriving the brain of the blood it requires, which causes brain cells to degenerate [1].

The World Heart Federation said in 2015 that 15 million individuals experience a stroke annually, with 6 million of them dying and 5 million developing a lasting impairment. [2]. Stroke cases account for 70% of all cases worldwide in low- and middle-income nations, and 87% of stroke deaths occur in these countries as well. Stroke incidence has decreased by 42% in high-income countries in recent decades [3]. The majority of stroke patients have general disabilities such as paralysis and weakness on one side


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of the body, which can interfere with their daily functional activities [4]. Impaired walking is a major issue for the majority of stroke survivors because it interferes with daily activities and increases the risk of falling [5]. A change in normal gait as determined by spatiotemporal, kinematic, and kinetic profiles, as well as energy expenditures, is called post-stroke gait, also known as hemiparetic gait. [6]. Hemiparetic gait is distinguished by a significant reduction in speed and asymmetry, as well as shorter stride and stride lengths. There are changes in stance and swing periods, as well as changes in angular parameters [7].

During the loading response, there is an increase in knee flexion and a decrease in hip flexion, as well as a decrease in plantar flexion and hip extension, causing the knee to hyperextend. Excessive leg circumduction or hip flexion allows adequate leg distance during the swing phase, in addition to decreased knee flexion [8]. Changes in gait patterns in stroke patients are generally asymmetric, and walking speed is reduced due to stride and stride length deviations, as well as muscle weakness [8]. Changes in the stance and swing phases are common in stroke patients. The stance and midstance phases are shorter on the hemiplegic side, and the swing phase is longer [9]. The asymmetrical pattern can be measured in a variety of ways, which are generally classified into two broad categories: spatial and temporal. Spatial asymmetry is typically measured by comparing the stride length from the paretic to the non-paretic foot, whereas temporal asymmetry is measured by the swing relationship or single limb support time (SLS) between the legs. In one study, the asymmetric walking pattern was dominated by one asymmetrical pattern with shorter nonparetic steps [10].

Walking cadence and stride length both affect speed (number of steps per minute). The speed of spontaneous gait (spontaneous gait) in healthy individuals is 1.0 - 1.5 m/s, whereas it decreases by approximately 0.08 m/s - 1.05 m/s in hemiparetic subjects. According to Bohannon, the average rhythm in healthy individuals is 115 steps/minute; however, after a stroke, the rhythm can decrease between 27.9 - 47.2 steps/minute and 57 steps/minute, according to Brandstater[8]. In a recent study, not only the front and back sides of the legs, but also the lateral sides, particularly the pelvis, differed from healthy subjects depending on walking speed in hemiparetic subjects. The duration and proportion of the gait cycle phase influence change in gait speed, cadence, and stride length [8].

A treadmill intervention was given to post-stroke patients in a study, and it was found to increase walking speed, walking adaptability, cognitive dual- task performance, and cognitive-motor interference (cognitive dual-task performance and cognitive-motor interference). Superior to FALLS's overground intervention program [11]. Furthermore, the treadmill can increase VO2 max, as measured by the distance traveled in 6 minutes. Whereas an increase in VO2 max indicates an increase in tolerance to the activities performed. The greater the distance traveled, the greater the amount of oxygen required [12]. According to a recent study, regardless of the severity of the disorder, locomotor training on a treadmill can improve gait speed and walking endurance after 30-36 treatment sessions performed three times per week for 90 minutes [13]. In contrast, Middleton et al (2014), found that while the treadmill intervention did not result in significant changes in functional (walking patterns, balance, and mobility), it did result in a significant change in walking speed [14]. The goal of this research is to determine the various effects of a treadmill on walking patterns after a stroke.

## 2 Method

This study is a literature review. The author creates a synthesis of articles based on the research results, which begins with analyzing relevant articles on the topic of discussion that will be reviewed by the author, by making identification and classification based on elements that have been determined, with the same topic of discussion. The search for scientific articles was conducted using databases from PubMed, ScienceDirect, ResearchGate, and Cochrane that were published between 2012 and 2022. The terms treadmill, gait pattern, and stroke were used to search the database. The authors screened titles and abstracts for relevant studies, then reviewed the studies to see if they met the predetermined criteria.

Articles were reviewed using the PICO (population, intervention, comparison, outcome) framework, and the quality of the research methodology was determined by calculating the score on the PEDro scale, which consists of 11 items. The PEDro quality assessment scale includes the following features: (1) subject eligibility criteria; (2) groups of participants were randomly allocated.; (3) subject allocation is hidden; (4) groups had comparable characteristics at baseline for the most crucial prognostic factors; (5) all subjects in the study were blinded; (6) all therapists providing therapy were blinded; and (7) all raters were blinded to ratings for at least one major outcome. (8) At each given time point, more than 85% of the individuals had at least one main outcome; (9) At least one primary outcome was evaluated with "intention to treat" if all individuals for whom the outcome measure was allocated got the treatment or controlled condition as assigned; (10) At least one main result is reported in the form of statistical comparison results between groups; (11) This article gives a point measure and variability for at least one key outcome. Except for point (1), which is an external validity reference, all other points accept "Yes" or "No" based on the aspect criteria. A maximum score of 10 can be assigned to an article. Ratings are used to categorize the article as very good to bad, with a score of 9-10 considered very good, 6-8 considered good, 4-5 considered fair, and 4 considered bad.

The article's inclusion criteria included published in English, articles with randomized controlled trials (RCTs), who had a stroke within the previous more than two months and had walking disorders, using a treadmill as an intervention, and published between 2012 and 2022.

Treadmill, overground FALLS program, Overground gait training, treadmill-based C-Mill therapy, BWSTT, TWBS, task-oriented overground, PNF, TPBWS, and normal gait re-education were the interventions used in this study. Every study collected more than one measurement result before and after the intervention. Walking patterns, walking speed, balance, walking endurance, and walking adaptation ability were all measured using various instruments. The following measuring instruments were used in the research data sources: 10MWT, 6MWT, DGI, BBS, TUG, SSS, FAC, 3MWT, ABC scale, SLS, FM, PR, NIHSS, MAS, and Motor FIM scale.

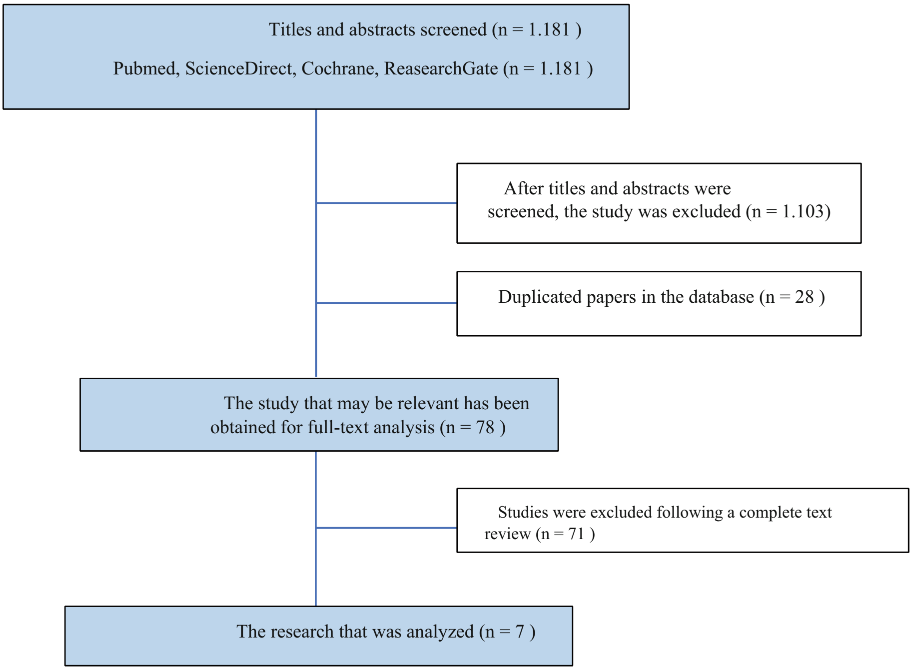


**Fig. 1.** The flow of the literature-searching process

## 3 Results

### 3.1 Article Search Results

The article search strategy was derived from 1,181 articles at first. Seven articles were chosen after being filtered by title, abstract, and potentially relevant studies. The inclusion criteria were not met by 71 articles. Figure 1 depicts the flow of the literature- searching process.

### 3.2 Inclusion Characteristics Included in the Study

Seven articles involving 599 participants were chosen to investigate the benefits of a treadmill for improving walking patterns after stroke [11, 13–18]. Table 1 contains more information.

### 3.3 Rating of Quality

The average PEDro scores of the included articles range from 5 to 8. Table 2 shows the PEDro criteria and scores. Table 2 contains more information.

**Table 1.** Characteristics of the study

| No | Author and Year | Journal | Location | Design |
|---|---|---|---|---|
| 1 | Baer et al. (2018) | Clinical Rehabilitation | Edinburgh, UK | Experimental |
| 2 | Mao et al. (2015) | Biomed Research International | China | Experimental |
| 3 | Middleton et al. (2014) | Top Stroke Rehabil | Columbia | Experimental |
| 4 | Ribeiro et al. (2013) | European Journal of physical and Rehabilitation | Brazil | Experimental |
| 5 | Rose et al. (2017) | Physical Therapy | California and Florida | Experimental |
| 6 | Srivastava et al. (2016) | Annals of Physical and Rehabilitation Medicine | India | Experimental |
| 7 | Timmermans et al. (2021) | Trials | Netherland | Experimental |

## 3.4 Participants

Participants were over the age of 18, had a stroke within the previous two months, had good cognitive abilities, had walking disorders, could walk alone or with assistance (orthosis), and were enrolled in a randomized controlled trial (RCT). Table 3 contains more information.

## 3.5 Interventions

### 3.5.1 Treadmill Training

At least three sessions of traditional physiotherapy and two sessions of treadmill walking training were given to research participants each week. [17].

### 3.5.2 Treadmill Based C-Mill

C-Mill is a walking pattern training device that uses a projector to project a visual that represents the target step or obstacle on the road surface. This medium recognizes route patterns and offers performance feedback. The C-Mill is further outfitted to allow interactive context projection in a gait- dependent way, permitting stride adjustment workouts under intense time constraints, which is challenging for patients recovering from strokes. [19].

### 3.5.3 Treadmill Without Bodyweight Support (TWBS)

TWBS is a treadmill training method in which the patient wears a harness for safety but receives no mechanical assistance [15].

**Table 2.** PEDro Scale

| Trial | Baer et al. (2018) | Middleton et al. (2014) | Mao et al. (2015) | Ribeiro et al. (2013) | Rose et al. (2017) | Srivastava et al. (2016) | Timmermans et al. (2021) |
|---|---|---|---|---|---|---|---|
| Random allocation | Y | Y | Y | Y | Y | Y | Y |
| Concealed allocation | N | Y | Y | Y | N | Y | Y |
| Groups similar at baseline | Y | Y | Y | Y | Y | Y | N |
| Participant blinding | N | N | N | N | Y | Y | N |
| Therapist blinding | N | Y | N | N | N | Y | N |
| Assessor blinding | Y | N | Y | Y | N | N | N |
| $< 15\%$ dropouts to follow-up | N | N | N | Y | Y | N | N |
| Intention-to-treat analyses | Y | N | Y | N | Y | Y | Y |
| Between-group difference reported | Y | Y | Y | Y | Y | Y | Y |
| Point estimate and variability reported | Y | Y | Y | Y | Y | Y | Y |
| **Total (0–10)** | **6/10** | **7/10** | **7/10** | **7/10** | **7/10** | **8/10** | **5/10** |

#### 3.5.4 Treadmill Training with Partial Bodyweight Support (TPBWS)

TPBWS is a type of gait training that uses a treadmill with a predetermined amount of body weight to reduce the load supported during training [16].

#### 3.5.5 Bodyweight Support Treadmill Training (BWSTT)

BWSTT is a technique for practicing walking patterns that involves wearing a harness that is suspended from a metal pole above. When walking on a treadmill, a harness and bodyweight support provide support to reduce the load on the legs. As needed, the amount of assistance can be gradually increased or decreased [15].

### 3.6 Control Group

Overground FALLS program [11], PNF [16], and normal gait re-education [17]. Overground gait training was used in four trials [13–15, 18].

**Table 3.** Subject Characteristic

| No | Author and Year | Number of Subjects | Subject Characteristics |
|---|---|---|---|
| 1 | Baer et al. (2018) | Seventy-sevenwith stroke sub-acute | Age > 18 years; 3-month onset stroke with sub-acute stroke; able to stand for 1 min with or without assistance (can use a harness if needed); medically stable; able to understand and follow verbal instructions, and has informed consent |
| 2 | Mao et al. (2015) | Twenty-four with stroke unilateral hemiparesis | Unilateral hemiparesis, stroke onset ≤ 3 months, residual gait disturbance, has an abnormal walking time of 10 m for age (age < 60 years = 10 s or 1 m/s; age 60–69 years: 12.5 s or 0.8 m/s; age 70 years: 16.6 s or < 0.6 m/s), Mini-Mental State Examination score ≥ 27, MAS in a hip, knee, and ankle ≤ 2. |
| 3 | Middleton et al. (2014) | Forty-three with stroke unilateral hemiplegia | Age ≥ 18 years; unilateral hemiplegia; chronic stroke patients > 6 months; willing to: follow three-step instructions; sit without back or arm support for five minutes; stand without an AD for five minutes with no more than Min A (minimal assistance); walk 20 feet with sporadic Mode A (moderate assistance) for balance; and independently advance an AD and both bilateral LEs during ambulation |

(*continued*)

**Table 3.** (*continued*)

| No | Author and Year | Number of Subjects | Subject Characteristics |
|---|---|---|---|
| 4 | Ribeiro et al. (2013) | Twenty-three with strokeunilateral hemiparesis | Age: 40 - 70 years old; the first stroke with unilateral hemiparesis chronic stroke; spasticity level 0 - 2 on the Modified Ashworth Scale MAS of muscle spasticity for the lower limb affected; FAC score 3- 5; stroke onset ≥ 6 months; absence of clinical signs of cardiac changes (New York Heart, grade 1); can walk as far as 10 m without the help of assistants or tools; not using orthotics on the paretic foot; can follow simple verbal commands |
| 5 | Rose et al. (2017) | Three hundred and forty-seven with a stroke | Stroke onset ≥ 2 months; able to walk 3 m with assistance; age > 18 years; residual paresis in lower extremities; self-selected 10m running speed less than 0.8m/s |
| 6 | Srivastava et al. (2016) | Forty-five with stroke ischemicor hemorrhagic | First attack stroke ischemic or hemorrhagic supratentorial lesion; right or left hemiparesis > 3 months; can walk independently or requires 1 person to assist with balance and coordination (Functional Ambulation Category [FAC] 2–4). |
| 7 | Timmermans et al. (2021) | Fortywithstroke ischemic | Ischemic stroke ≥ 3 months; Functional Ambulance Categories (FAC) ≥ 4; hemiparesis; current deficit and/or balance |

## 3.7 Outcome Measurements

Various measuring instruments used in this study to measure walking speed used 10MWT [11, 13, 15, 17] and 3MWT [14]; balance using the Barthel Index [17], TUG [14, 17], BBS [13, 14], DGI [14], SLS [14], ABC scale [14], FM [14], Brunel balance assessment [18]; for walking endurance using 6MWT [13, 14, 17]; walking ability using FAC [15–17]; to measure lower extremity muscle tone using the MAS [16, 17]; functional impairment, functional mobility, and activity limitation using SSS [15]; and Rivermead Mobility Index [17]; walking confidence was measured using the Confidence in Walking VAS [17]; to measure the quality of life and daily activities using the Motor FIM scale, SIS v3.0 [17]; and measurement of recovery status using PR [14].

### 3.8 Study Results

Table 4 showed that the study results of the benefits of the treadmill to improve the walking patterns that occur in post-stroke patients.

**Table 4.** Study Results

| No | Author and Year | Study Results |
|---|---|---|
| 1 | Baer et al. (2018) | 1. Rivermead Mobility Index (control: $p < 0.005$; treadmill training: $p < 0.005$)<br>2. Functional Ambulatory Category (control: $p < 0.005$; treadmill training: $p < 0.005$)<br>3. Barthel Index (control: $p < 0.005$; treadmill training: $p < 0.005$<br>Walking capacity, activities of daily life with treadmill training in an ambulance, and non-ambulance with subacute stroke did not significantly improve at 8 weeks or 6 months. For gait speed of more than 10m (0.45m/s versus 0.5m/s) and walking endurance of more than 6 min, treadmill training was equivalent but somewhat less effective post-intervention (119m vs 160m). Participants had somewhat higher baseline median Barthel Index scores for activities of daily living, but results after six<br>months were comparable. |
| 2 | Mao et al. (2015) | There was an improvement in balance and lower extremities motor function ($P < 0.05$), and there was no significant difference between the two intervention groups.<br>However, the kinematic data increased significantly ($P < 0.05$) after BWSTT but not after Overground gait training. Maximum hip extension and flexion angles increased significantly ($P < 0.05$) in the BWSTT group during the stance phase and swing phase compared to baseline. |
| 3 | Middleton et al. (2014) | The results of this study showed no significant changes in functional (walking pattern, balance, and mobility), but there was a significant increase in walking speed.<br>Chronic stroke patients may show improvement in gait, balance, and mobility after intensive therapy, but are limited to maintenance after 3 months. |

(*continued*)

**Table 4.** (*continued*)

| No | Author and Year | Study Results |
|---|---|---|
| 4 | Ribeiroetal (2013) | 1. The increase in STREAM scores (F = 49,189), P < 0.001) and FIM motor scores (F = 7.093, P = 0.016) after training, as well as an increase in the symmetry ratio swing time of the paretic leg or swing time of the non-paretic leg (F = 7.729, P = 0.012) in both groups.<br>2. Maximum dorsiflexion during the swing phase in the two groups differed over time (F = 6.046; P = 0.024), in the PNF group.<br>3. According to the results of research from this literature, the use of TPBWS is not effective in increasing ADL.<br>4. Improved temporal gait symmetry in both groups, with no change in velocity.<br>5. TPBWS can control the symmetry step and show an increase in stride length symmetry or velocity. |
| 5 | Rose et al. (2017) | Gait speed increased at 2 and 6 months after stroke and walking endurance increased after 36 sessions of treatment, but the rate of increase continued to decrease and averaged lowest at 25–26 sessions, regardless of the type of treatment or the severity of the disorder. |
| 6 | Srivastava et al. (2016) | 1. There was a significant increase in walking speed in the 3 groups and a significant increase in walking endurance except in the control group.<br>2. After training and during the three-month evaluation period, all outcome variables in the control group, except for walking endurance, showed a statistically significant improvement.<br>3. The BWSTT and TWBS groups showed a significant increase at the end of training (SSS, FAC, walking speed, walking endurance) and at the time of evaluation. |
| 7 | Timmermans et al. (2021) | 1. Walking speed on CT showed greater progress in using the 10MWT context than post-intervention FP. Walking speed (0.91 ± 0.28) to (0.06 ± 0.14)<br>2. Cognitive dual-task performance and cognitive-motor interference on CT showed better progress in cognitive performance during 10MWT with cognitive dual task compared to the FP group.<br>3. The cognitive motor does not show significant changes<br>4. The differences in outcomes between the interventions were not statistically significant, but on the post-intervention test, which was not statistically significant for retention, we observed better progress on the context-specific walking speed with the physical context of C-Mill therapy compared to the FALLS program. |

## 4 Discussion

Post-stroke walking patterns affect the walking cycle, which affects walking ability, speed, balance, endurance, and the ability to adapt to walking. Changes in walking patterns in stroke patients are the main factors that limit daily activities and put them at risk of falling [5]. The gait in stroke is generally asymmetries; by increasing the strain on the unaffected lower extremities, it may result in secondary injury. Changes in walking patterns include step length, step time, and gait line length, all of which are related to balance [9].

Good quality articles support the positive impact of providing a treadmill to improve walking patterns in post-stroke patients. According to the findings of this literature review, a treadmill not only increases walking speed (Table 3) and walking endurance, but it also improves functional activities such as walking patterns, balance, and mobility, though the results are not statistically significant [11, 14]. Four studies found that using a treadmill improved walking speed and endurance [11, 13–15]. One study found that after intensive therapy, chronic stroke patients' balance, gait, and mobility improved significantly, though this improvement could only be maintained for three months [14].

In one study, BWSTT was shown to improve walking endurance in post-stroke subacute stroke patients, but there was no improvement in balance or walking speed at 10 meters [20]. According to Mao et al (2015), 3 weeks of treadmill training with bodyweight support can improve balance and lower extremity function in subacute stroke patients, as well as spatiotemporal parameters [18]. Increased hip joint movement while walking is associated with an improved gait pattern. Furthermore, treadmill exercise can improve cognitive dual-task performance, cognitive-motor interference, and walking adaptability using the treadmill-based-C-Mill method, as measured by the 10MWT with or without both contexts [11].

In terms of walking parameters, an increase in walking speed can result in functional changes such as improved quality of life and social adaptation [21]. Treadmill training with partial body-weight support (TPBWS) was found to be less effective in improving daily activities [16, 17], but it was able to control step symmetry and showed an increase in stride length symmetry or velocity when compared to the control group, can increase maximum dorsiflexion during the swing phase. According to Baer et al (2018), using a treadmill at an intensity of 2 times per week for 8 to 16 minutes in sub-acute stroke patients, there was no significant improvement in walking ability or daily activities after 8 weeks or 6 months after surgery on participants in an ambulance (FAC 4-6) and non-ambulant (FAC 1-3) post-training [17].

Treadmill training did not affect on speed or endurance when used less than three times per week [22]. The dosage is the primary factor that affects how well an intervention works to enhance motor and behavioral function after a stroke. In physical rehabilitation, exercise parameters such as frequency, intensity, duration, and type all play a role in the dose- response relationship [23]. According to Rose et al (2018), the use of a treadmill can increase walking speed and endurance after 30-36 during 90-minute exercise sessions, regardless of severity [13].

A treadmill can improve walking performance in chronic stroke patients, with a peak speed of 20 minutes increasing oxygen uptake and high loads and repetitive training increasing endurance [24, 25]. According to one study, treadmills with *or* without bodyweight support were more effective than traditional therapy in improving locomotor dynamics. Because this type of exercise is well tolerated by post- stroke patients and the strategy is consistent with clinical practice [15]. Typical stroke physiotherapy includes position changes, breathing exercises, and exercise therapy in passive and active mobilization. There is no standard for this setting because it will adjust to needs, but conventional therapy is not always effective [26].

High-intensity treadmills, in addition to causing walking disorders, can have an impact on cardiorespiratory fitness. High-intensity treadmills with a target heart rate of 40-60% of the reserve heart rate have been shown to reduce disability and improve cardiorespiratory fitness in chronic stroke patients, but this type of exercise is typically not initiated during inpatient rehabilitation [27–29]. In addition to physical training in post-stroke patients, it is necessary to educate the family on what they can do to overcome problems that may arise as a result of the stroke. Furthermore, the family plays a critical role in efforts to improve independence, self-confidence, and disability in stroke patients [30].

The above review obtained an average PEDro score of 6.71 from seven high-quality trials included. The characteristics of the participants were similar, and the time to stroke ranged from subacute to chronic.

In this review, no one described changes in the phases of the gait pattern in detail, only changes in walking speed, gait adaptability, walking endurance, and gait balance. More research is required to obtain more detailed results of the road pattern phases.

## 5 Conclusion

An overview of the literature reveals that using a treadmill to improve walking patterns after stroke can improve walking speed, ability, adaptability, and balance in acute, subacute, and chronic stroke patients, but it must be done at a minimum of three times per week to complete a full treadmill workout.

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## References

1. U. B. Rahayu, "Peningkatan Kapasitas Kesehatan Pasien Pasca Stroke Pada Komunitas Stroke Di Solo Selatan," *War. LPM*, vol. 21, no. 2, pp. 27–30, 2019, doi: https://doi.org/10.23917/warta.v21i2.8131.
2. World Health Organization, *World Health Statistics 2015*, vol. 13, no. 3. 2015.

3. W. Johnson, O. Onuma, M. Owolabi, and S. Sachdev, "Stroke: a global response is needed," *Bull. World Health Organ.*, vol. 94, no. 9, pp. 634A-635A, Sep. 2016, doi: https://doi.org/10.2471/BLT.16.181636.
4. S. Yaghi *et al.*, "Treatment and Outcome of Hemorrhagic Transformation After Intravenous Alteplase in Acute Ischemic Stroke: A Scientific Statement for Healthcare Professionals From the American Heart Association/American Stroke Association," *Stroke*, vol. 48, no. 12, pp. e343–e361, 2017, doi: https://doi.org/10.1161/STR.0000000000000152.
5. C. Beyaert, R. Vasa, and G. E. Frykberg, "Gait post-stroke: Pathophysiology and rehabilitation strategies," *Neurophysiol. Clin.*, vol. 45, no. 4–5, pp. 335–355, 2015, doi: https://doi.org/10.1016/J.NEUCLI.2015.09.005.
6. B. Callegari *et al.*, "Gait patterns in ischemic and hemorrhagic post-stroke patients with delayed access to physiotherapy," *Hong Kong Physiother. J.*, vol. 41, no. 2, pp. 77–87, 2021, doi: https://doi.org/10.1142/S1013702521500074.
7. P. Y. Lin, Y. R. Yang, S. J. Cheng, and R. Y. Wang, "The relation between ankle impairments and gait velocity and symmetry in people with stroke," *Arch. Phys. Med. Rehabil.*, vol. 87, no. 4, pp. 562–568, Apr.2006, doi: https://doi.org/10.1016/J.APMR.2005.12.042.
8. S. Nadeau, M. Betschart, and F. Bethoux, "Gait analysis for poststroke rehabilitation: The relevance of biomechanical analysis and the impact of gait speed," *Phys. Med. Rehabil. Clin. N. Am.*, vol. 24, no. 2, pp. 265– 276, 2013, doi: https://doi.org/10.1016/j.pmr.2012.11.007.
9. S. D. Yoo *et al.*, "Biomechanical Analyses of Gait and Balance in Patients with Subacute Stroke," 2022, doi: https://doi.org/10.21203/rs.3.rs-1503568/v1
10. V. L. Little, L. A. Perry, M. W. V. Mercado, S. A. Kautz, and C. Patten, "Gait asymmetry pattern following stroke determines acute response to locomotor task," *Gait Posture*, vol. 77, no. February, pp. 300–307, 2020, doi: https://doi.org/10.1016/j.gaitpost.2020.02.016.
11. C. Timmermans, M. Roerdink, C. G. M. Meskers, P. J. Beek, and T. W. J. Janssen, "Walking-adaptability therapy after stroke: results of a randomized controlled trial," *Trials*, vol. 22, no. 1, pp. 1–13, 2021, doi: https://doi.org/10.1186/s13063-021-05742-3.
12. N. P. Amalia and M. I. Rahman, "Latihan Endurance Penderita Pasca Stroke Iskemik," *FISIO MU Physiother. Evidences*, vol. 3, no. 1, pp. 23–28, 2021, doi: https://doi.org/10.23917/fisiomu.v3i1.14351.
13. D. K. Rose *et al.*, "Locomotor training and strength and balance exercises for walking recovery after stroke: Response to number of training sessions," *Physical Therapy*, vol. 97, no. 11. pp. 1066–1074, 2017. doi: https://doi.org/10.1093/ptj/pzx079.
14. A. Middleton *et al.*, "Body weight-supported treadmill training is no better than overground training for individuals with chronic stroke: a randomized controlled trial," *Top. Stroke Rehabil.*, vol. 21, no. 6, pp. 462–476, Jan. 2014, doi: https://doi.org/10.1310/TSR2106-462
15. A. Srivastava, A. B. Taly, A. Gupta, S. Kumar, and T. Murali, "Bodyweight- supported treadmill training for retraining gait among chronic stroke survivors: A randomized controlled study," *Ann. Phys. Rehabil. Med.*, vol. 59, no. 4, pp. 235–241, 2016, doi: https://doi.org/10.1016/j.rehab.2016.01.014.
16. T. Ribeiro, H. Britto, D. Oliveira, E. Silva, E. Galvão, and A. Lindquist, "Effects of treadmill training with partial body weight support and the proprioceptive neuromuscular facilitation method on hemiparetic gait: A randomized controlled study," *Eur. J. Phys. Rehabil. Med.*, vol. 49, no. 4, pp. 451–461, 2013.
17. G. D. Baer, L. G. Salisbury, M. T. Smith, J. Pitman, and M. Dennis, "Treadmill training to improve mobility for people with sub- acute stroke: a phase II feasibility randomized controlled trial," *Clin. Rehabil.*, vol. 32, no. 2, pp. 201–212, 2018, doi: https://doi.org/10.1177/0269215517720486.
18. Y. R. Mao *et al.*, "The Effect of Body Weight Support Treadmill Training on Gait Recovery, Proximal Lower Limb Motor Pattern, and Balance in Patients with Subacute Stroke," *Biomed Res. Int.*, vol. 2015, 2015, doi: https://doi.org/10.1155/2015/175719.

19. K. Smulders, R. van Swigchem, B. J. M. de Swart, A. C. H. Geurts, and V. Weerdesteyn, “Community-dwelling people with chronic stroke need disproportionate attention while walking and negotiating obstacles,” *Gait Posture*, vol. 36, no. 1, pp. 127–132, May 2012, doi: https://doi.org/10.1016/J.GAITPOST.2012.02.002.
20. M. MacKay-Lyons, A. McDonald, J. Matheson, G. Eskes, and M. A. Klus, “Dual effects of body-weight supported treadmill training on cardiovascular fitness and walking ability early after stroke: A randomized controlled trial,” *Neurorehabil. Neural Repair*, vol. 27, no. 7, pp. 644–653, 2013, doi: https://doi.org/10.1177/1545968313484809.
21. J. Lindberg and J. Carlsson, “The effects of whole-body vibration training on gait and walking ability - a systematic review comparing two quality indexes,” *Physiother. Theory Pract.*, vol. 28, no. 7, pp. 485–498, 2012, doi: https://doi.org/10.3109/09593985.2011.641670
22. J. Mehrholz, S. Thomas, and B. Elsner, “Treadmill training and body weight support for walking after stroke,” *Cochrane Database Syst. Rev.*, vol. 2017, no. 8, Aug. 2017, doi: https://doi.org/10.1002/14651858.CD002840
23. W. R. Thompson, N. F. Gordon, and L. S. Pescatello, *ACSM Guidelines for Exercise Testing and Prescription.* 1386.
24. C. Globas *et al.*, “Chronic stroke survivors benefit from high-intensity aerobic treadmill exercise: A randomized control trial,” *Neurorehabil. Neural Repair*, vol. 26, no. 1, pp. 85–95, 2012, doi: https://doi.org/10.1177/1545968311418675.
25. W. Choi, D. Han, J. Kim, and S. Lee, “Whole-body vibration combined with treadmill training improves walking performance in post-stroke patients: A randomized controlled trial,” *Med. Sci. Monit.*, vol. 23, pp. 4918–4925, 2017, doi: https://doi.org/10.12659/MSM.904474.
26. U. B. Rahayu, S. Wibowo, I. Setyopranoto, and M. Hibatullah Romli, “Effectiveness of physiotherapy interventions in brain plasticity, balance and functional ability in stroke survivors: A randomized controlled trial,” *NeuroRehabilitation*, vol. 47, no. 4, pp. 463–470, 2020, doi: https://doi.org/10.3233/NRE-203210.
27. D. H. Saunders *et al.*, “Physical fitness training for stroke patients,” *Cochrane database Syst. Rev.*, vol. 3, no. 3, Mar. 2016, doi: https://doi.org/10.1002/14651858.CD003316
28. D. L. Marsden, A. Dunn, R. Callister, C. R. Levi, and N. J. Spratt, “Characteristics of exercise training interventions to improve cardiorespiratory fitness after stroke: A systematic review with meta-analysis,” *Neurorehabil. Neural Repair*, vol. 27, no. 9, pp. 775–788, 2013, doi: https://doi.org/10.1177/1545968313496329.
29. S. G. Brauer, S. S. Kuys, J. D. Paratz, and L. Ada, “Improving physical activity after stroke via treadmill training and self management (IMPACT): A protocol for a randomised controlled trial,”BMC Neurol., vol. 18, no. 1, pp. 1–8. 2018, doi: https://doi.org/10.1186/s12883-018-1015-6.
30. W.N. Irdawati dan Ambarwati, “Hubungan antara Pengetahuan dan Sikap Keluarga dengan Perilaku dalam Meningkatkan Kapasitas Fungsional Pasien Pasca Stroke di Wilayah Kerja Puskesmas Kartasura,“Ber. Ilmu Keperawatan vol.2 , pp. 63–68, 2009