International Journal of Health Sciences and Research
DOI: https://doi.org/10.52403/ijhsr.20210721
Vol.11; Issue: 7; July 2021
Website: www.ijhsr.org
Review Article *ISSN: 2249-9571*

Functional Gait of Patients with Stroke after Strength Training: A Systematic Review of Randomised Controlled Trials

Marjorie R. Mwansa[1], Simon Himalowa[1], Richard Kunda[2]

[1]Department of Physiotherapy, Lusaka Apex Medical University, Lusaka, Zambia
[2]School of Health Sciences, Levy Mwanawasa Medical University, Lusaka, Zambia

Corresponding Author: Marjorie R. Mwansa

ABSTRACT

Background: Stroke is a major health challenge that impacts on the independence, quality of life, productivity and participation in social and economic lives of patients with stroke.
Objective: To determine the effects of strength training on functional gait of stroke patients compared to conventional therapy
Methods: Eleven databases (PubMed, Science Direct, MEDLINE, PEDRO, Cochrane, EBSCO Host, CINAHL, PsycInfo, Embase, Google Scholar and ERIC) were searched to identify eligible studies. All randomised controlled trials published between 2010 and 2020 were included and reviewed by two independent reviewers. The Critical Appraisal Skills Programme (CASP) checklist for RCTs was used to assess and appraise the studies.
Main Results: This review analysed 16 studies involving 946 patients with stroke that reported on aerobic exercises, task-oriented circuit training, treadmill gait training, high and medium intensity interval training, dynamic resistance training, progressive resistance training, stationary cycling, concentric isokinetic strengthening, functional strength training, resistance exercise strengthening, and isokinetic strengthening. The interventions revealed a statistical significance on walking speed, gait parameters, mobility, muscle strength, quality of life, functional parameters and balance of subjects from the strength training groups.
The mean changes in gait speed, walking distance and mobility increased in the experimental (strength training) than the control (conventional) group ($p = 0.003$, $p=.038$; SD 0.25/0.33, $p < .0001$). Comparing walking speed at pre- and post-intervention, stride length increased (48.00 5.63: 53.00 5.38) with a p-value of $p< 0.05$. However, no statistical significance was recorded between the paretic and non-paretic limb during swing phase (paretic $p = 0.0089$; non-paretic $p = 0.074$). Strength training significantly improved all knee strength and ankle parameters, and gait velocity ($p<0.01$, $p<0.05$).
Conclusion: Strength training appears to be an effective intervention improving functional gait of stroke patients compared to conventional therapy.

Key Words: Stroke patient, Functional gait, Strength training

1. BACKGROUND

Stroke often requires urgent treatment in order to mitigate the neurological damage to victims [1]. According to [2], stroke is the highest leading cause of disability in adults living in industrialized countries. It is a major health challenge worldwide that leads to persistent residual impairments [3]. Individuals with stroke often have gait impairments that impact on their independence, quality of life, productivity and participation in social as well as economic life [9, 6, 11]. The impact of stroke is such that patients with stroke amounting to approximately 26.1% and 26.3% remain disabled for as long periods of time as 1-3 years post stroke [12]. At least 15-30% of patients with stroke have long-term disability [7]. In addition, stroke poses a huge financial burden on both society and the individuals affected by stroke [13]. In spite of long rehabilitation interventions, some patients with stroke still remain with residual disability [1].

Literature shows that 80% of patients with stroke experience inability to walk and perform independent activities of daily living [4, 15]. Although most of them regain the ability to walk, 40% of them require assistance with walking [15]. In the UK, the prevalence of stroke is believed to be between 178:100000 and 317:100000 in the population each year [13].

There is a correlation between gait speed, gait endurance, physical performance and functional balance, and muscle strength of the lower limbs [4]. In particular, functional performances associated with stroke include the inability to stand, perform transfers, climb stairs, and gait [14]. Therefore, lower limb muscle weakness resulting from stroke leads to reduced gait speed, endurance, performance, participation and balance [2, 3, 4, 13, 18].

Gait dysfunction is a major hindrance to functional mobility and manifests as an asymmetrical deficit affecting gait patterns [2, 4, 10, 19]. Hemiparesis, an asymmetrical motor impairment affects 65% of patients with stroke and over 30% of individuals with stroke suffer from gait asymmetry [2, 10]). Gait is often quantified in relation to distance (spatial) and timing (temporal). Furthermore, these authors feel that the equalization of spatial and temporal variables in gait contributes to symmetrical gait. According to [4], walking speed, which is often reduced in patients with stroke, is cardinal in assessing gait performance. The normal walking speed in healthy individuals is 1.3m/s while in paretic individuals it is between 0.23-0.73 m/s. However, stroke does not only affect one side of the body that manifests as paresis of the arm and leg, but also affects trunk muscles on both sides, leading to imbalance and difficult gait [9].

The study by [20], revealed an increase in patients with stroke who have limitation in activities of daily living (ADL) leading to dependency on rehabilitation intervention. The current practice in stroke management and rehabilitation focuses on acute and sub-acute stages with only a few paying attention to 6 months and beyond [13].

However, the quest for evidence-based interventions seems to point to progressive resistance training (PRT) as a remedy to improve muscle strength, gait performance, perceived participation, and quality of life [12, 18]. Other beneficial effects of resistance training on post stroke patients are improved walking, stair climbing, chair-stand, and upper limbs function, especially reaching out [21]. Several studies show that early rehabilitation can improve balance and motor function [11]. Although [5] suggests that rehabilitation of patients with stroke has no standard method. The core aim of post-stroke rehabilitation is to restore independent and gait function [4] [10]. Literature suggests various forms of rehabilitation to restore gait in patients with stroke, namely conventional and contemporary management [4, 5]. Conventional management is the traditional management of gait dysfunction that includes the use of walking aids such as ankle foot orthotics (AFO).

On the other hand, contemporary management has a variety of components such as strength training, progressive exercises, functional strength training (FST), body weight support treadmill training, mental imaging/practice, mirror therapy, balance training, early intensive gait training, rhythmic pattern exercise, and over ground training [4, 5, 19]. Other interventions are motor learning, task-specific training, constraint-induced movement therapy, robotic-assisted training and virtual training [5]. Exercise training help to augment motor function and cognitive ability in post stroke patients [7, 10, 15]. The commonest exercise models are forced treadmill training and body-weight support treadmill, voluntary wheel training, and involuntary muscle contraction induced by electrical stimulation.

2. METHODS

2.1 Inclusion and exclusion criteria for studies

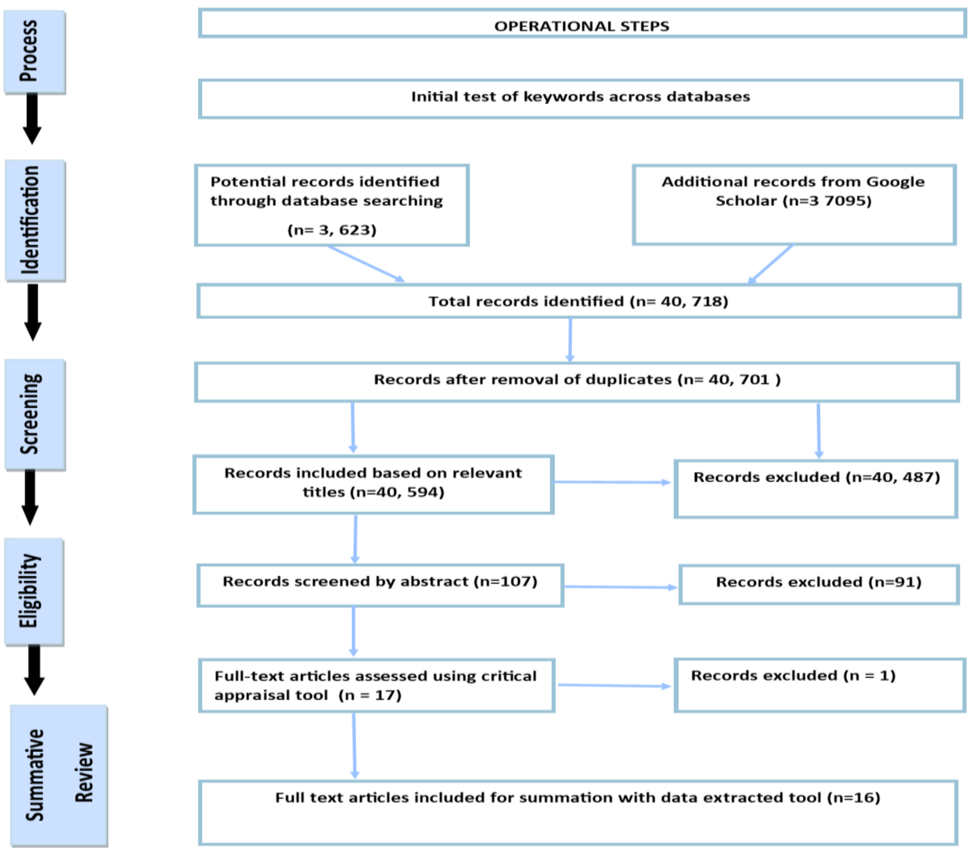
This procedure helped to focus on studies whose participants were patients with stroke and the comparison intervention was strength training either by progressive resistance, specific task functioning, and intensive aerobic exercising, these studies met the inclusion criteria. Although all these articles focused on strength training activities the duration and intensity of training were diverse in most of the articles. Figure 1 below illustrates details of search results.

2.2 Primary or secondary outcome measures

The International Classifications of Functioning, Disability and Health (ICF) defines activity limitation as challenges that an individual encounters in executing activities, and participation restriction as difficulties encountered by an individual in life situations (WHO, 2001). According to WHO, walking is one of the main domains under the ICF for activity limitation and participation restriction [2], describe in detail various tests that are regularly used to measure outcomes in literature. For example, Six Minute Walking (6MWT) and 10-Metre Walking test (10MWT) are used to assess walking, one repetition maximum (1 RM) and Manual muscle testing (MMT) to measure muscle strength, Timed Up-and-Go (TUG) and five times sit-to-stand test (SIS) for balance, and Berge Balance Scale (BBS) is recommended for measuring functional activities and balance.

2.2 SEARCH STRATEGY

Figure 1: Process of Systematic Review (Adapted from Moher et al., 2009)



A comprehensive systematic search of the literature was sought to identify all relevant studies. Relevant studies were searched mainly from two sources, such as electronic databases and reference lists. Electronic database searches were conducted in PUBMED, SCIENCE DIRECT, MEDLINE, PEDRO, COCHRANE, EBSCO HOST, CINAHL, PSYCINFO, EMBASE, GOOGLE SCHOLAR and ERIC from 2010 to 2020.

The search only considered randomised controlled trials with a control arm. Reference lists of relevant studies and reviews were equally hand searched to identify additional potential studies. Only Science Direct, Google Scholar, PubMed and EBSCOHOST yielded results according to the criteria of the search conducted. The following MeSH terms were used as search strategies; Exercises OR resistance training AND stroke OR cardiovascular accident, OR strengthening exercise OR physical activities OR circuit training OR progressive resistance training AND functional gait OR functional walking OR walking style OR walking speed. Boolean operators "and" and "or" were used in some databases. Other databases did not produce any results except the ones given in Table 1.

2.3 Identification of articles

Firstly, an individual reviewer screened out obvious irrelevant titles. Secondly, two authors reviewed the titles and abstracts for suitability and possible inclusion and rejected those that did not meet the inclusion criteria. During this process, all unsuitable studies were omitted from this review and duplicated articles were removed.

2.4 Critical appraisal of articles

Table 1: Methodological Quality Scores of included studies

Author & Year	Title	Database	Level of evidence	Methodological quality (CASP score)
Cooke et al. 2010	Efficacy of functional strength training on restoration of lower-limb motor function early after stroke: Phase I RCT 144	SCIENCE DIRECT	RCT	8/11
Flansbjer et al. 2012	Long term benefits of progressive resistance training in chronic stroke: A 4yr follow-up	PUBMED	RCT	7/11
Van de Port et al. 2012	Effects of circuit training as alternative to usual physiotherapy after stroke: RCT	PUBMED	RCT	7/11
Clark & Patten 2013	Eccentric vs concentric resistance training to enhance neuromuscular activation & walking speed following stroke	PUBMED	RCT	7/11
Lee & Kang, 2013	Effects of isokinetic eccentric resistance exercise for the hip joint on functional gait of stroke patients	GOOGLE SCHOLAR	RCT	8/11
Shahid et al. 2013	Effectiveness of strength training in post stroke	GOOGLE SCHOLAR	RCT	10/11
Chen et al. 2015	Comparison of the effects between isokinetic & isotonic strength training in subacute stroke patients	GOOGLE SCHOLAR	RCT	9/11
Kim et al. 2015	Effects of stationary cycling exercise on the balance & gait abilities of chronic stroke patients	GOOGLE SCHOLAR	RCT	8/11
Sen et al. 2015	Effects of the bilateral isokinetic strengthening training on functional parameters, gait & QoL in pts with stroke	GOOGLE SCHOLAR	RCT	10/11
Kerr et al. 2015	Functional strength training & movement performance therapy produce analogous improvement in SIS early after stroke RCT	GOOGLE SCHOLAR	RCT	8/11
Park et al., 2016	RCT pilot of truncal exercises after stroke to improve gait & muscle activity	EBSCOHOST	RCT	8/11
Boyne et al. 2016	High intensity interval training and moderate continuous training in ambulatory chronic stroke: A feasibility study	PUBMED	RCT	7/11
Druzbicki et al. 2018	Efficacy of gait training using a body weight support treadmill and visual biofeedback in patients with subacute stroke: RCT	PUBMED	RCT	9/11

Table 1 Continued…				
Joen & Hwang, 2018	Effects of bilateral lower limb strengthening exercises on balance & walking in hemiparetic patients after stroke: RCT	GOOGLE SCHOLAR	RCT	8/11
Nave et al. 2019	Physical fitness training in patients with subacute stroke: multicentre RCT	PUBMED	RCT	10/11
Fotiadou et al. 2019	Effect of exercise on gait kinematics and kinetics in patients with chronic ischaemic stroke	EBSCOHOST	RCT	7/11

Those deemed suitable were evaluated and appraised using the Critical Appraisal Skills Programme (CASP) checklist, one of the tools used to appraise randomised controlled trials and systematic reviews [27]. This tool contains 11 scoring points with a three-point Likert scale. The scores are classified as good if the points are between 8-11/11, moderate if the scores are from 5-7/11 and poor from 1-4/11. Out of 107 selected articles, 91 were excluded on grounds of not meeting the methodological quality. Only 16 articles met the criteria on methodological quality scores as shown in Table 1 below.

3. RESULTS

Description of studies

3.0 Results of search

The search yielded 40, 718 randomised controlled trials (RCTs). Out of this number, 16 duplicate articles and one in Chinese language were excluded. Furthermore, 40, 594 were removed upon screening of titles and abstracts leaving 107 articles for screening. On full-text scrutiny, 91 studies were removed because they were systematic reviews rather than randomised controlled trials and 16 were returned.

3.1 Characteristics of included studies

The included studies comprised of published journal articles involving 946 patients with stroke. These studies were conducted from 11 countries and none from Africa was included. Studies were published between 2010 and 2020 with most (15) of them published after 2010. We also identified on-going studies [22, 25] which were done as pilot studies. The number of participants ranged from 6 to 250 patients with stroke and most studies (12) had <50 participants.

All 16 studies included in this review had a mixture of gender with more male than female participants. The age of participants ranged between 18 and 90 years (± 3.45, ± 13.5). However, nine studies indicated the mean age and the standard deviation [8, 12, 16, 18, 19, 22, 23, 28, 29]. Four studies indicated the age range [1, 14, 20, 25] while three studies did not indicate the age range and gender [10, 15, 21]. This review included patients with stroke from sub-acute to chronic stage with one week to 69 months of occurrence of [1, 8, 10, 12, 14, 18, 19, 21, 23, 25, 28 29]. Three studies did not indicate the length of time post stroke [15, 16, 22].

The duration of intervention was from 3 to 12 weeks. However, most of the articles were in the range of 4 weeks [12, 14, 20, 25], and 6 weeks [16, 19, 23, 29]. Four articles included a follow-up programme on patients post intervention for 3-6 weeks [16], 12 weeks [23, 29], and 4 years [18]. The intensity ranged from 2-5 times a week for a minimum of 25 minutes to a maximum of 90 minutes. The time lapse since stroke was between 4 weeks to <24 months.

Included studies had one or more topics that included those focusing on effects (n=8) of an exercise programme, on gait kinematics and kinetics (n=1), trunk exercise on gait and muscle activity (n=1), task-oriented circuit training on walking (n=1), stationary cycling exercise on balance and gait (n=1), bilateral isokinetic strengthening on balance, gait and quality of life (n=1), resistance exercise strengthening of hip muscles on functional gait (n=1), bilateral lower limb strengthening on balance and walking (n=1). The next category had three (3) studies that focused on the efficacy of functional strength training of patients with stroke (n=1), aerobic exercise on ADL (n=1), strength training (n=1). Another category of five (5) studies focused on comparison of various strength training activities, functional strength training (FST) and conventional physiotherapy (CPT) (n=1), high intensity interval training (HIT) and medium intensity interval continuous training (MCT) (n=1), eccentric resistance training (ECC) to concentric resistance training (CON) (n=1), isokinetic and isotonic strengthening (n=1), functional strength training (FST), movement performance training (MPT) and conventional therapy (CPT) (n=1). The last study looked at benefits of progressive resistance training (n=1). A summary of characteristics of included studies are shown in Table 2 below.

3.2 Effects of interventions and comparison

3.2.1 Effects of strength training on mobility and walking speed

Out of 16 studies included in this review, seven tested for mobility in relation to walking or gait speed and generally there was a significant increase in muscle strength in subjects from the experimental group [8, 10, 20, 21, 22, 23, 25]. Walking speed increased for both the experimental and control groups with a statistical significance of p = .031, but participants in the experimental group improved more with p = .038 and the standard deviation was 0.25/0.33 [23]. Walking speed and walking cycle improved significantly from pre to post intervention [20], and in turn affected stride length (48.00 5.63: 53.00 5.38) with a p-value of p< 0.05. [25], compared HIT and MCT 6-minute walk test which showed 0.00(95% CI: -1.16) and 0.97 (95% CI: -0.25 TO 2.16).

Gait parameters between the experimental and the control groups were compared between the paretic and non-paretic limbs. There was no statistical significance between the experimental and control groups on the paretic and non-paretic limb during swing phase (paretic p = 0.0089; non-paretic p = 0.074). The mean number of steps between the two groups had a statistical significance of p = 0.007. The mean changes in gait speed, walking distance and mobility increased in the experimental than the control group at p = 0.003 [10]. Walking speed for concentric and eccentric group was tested as self-selected and fast walking speed for both types increased at CON, p =.002; ECC, p < .0001, CON, p = .0006; ECC, p < .0001. Walk tests such as 6 MWT and 10 meter walk test increased in the experimental (Eccentric group) than the control group (Concentric group) with a statistical significance of p < .0001 [8]. Clark and Patten (2013) show that the eccentric group was significantly greater than concentric group (ECC 81%, CON 42%, p = .04).

3.2.2 Effects of strength training on muscle strength and power

Six articles tested the strength of muscles around the hip and knee joints using isotonic or isokinetic force, concentric and eccentric resistance strength training [1, 8, 12, 16, 18, 21]. The experimental group increased in isotonic muscle strength by 30-70% (p<0.001) compared to isokinetic muscle strength that increased by 8-87% with a p-value (p<0.05). [16], compared conventional physiotherapy and isokinetic eccentric resistance for the hip flexors and extensors. The muscle strength and gait velocity in the isokinetic eccentric resistance group showed significant improvement (p<0.05) than the control group (Conventional physiotherapy).

The experimental group in [12], performed isokinetic strength training of knee flexion and extension, and the control group isotonic did isotonic strengthening. Comparing the two types of strength training, all knee strength parameters improved with a statistical significance in experimental isokinetic group than the isotonic control group, the degree of improvement between the two groups was insignificant. [8], assigned the experimental group to bilateral isokinetic strength training and the control group to conventional physiotherapy.

There was a significant improvement in both the paretic and non-paretic knee and ankle of the experimental group ($p<0.01$).The quality of life and functional parameters were higher from the experimental ($p<0.025$) than the control group ($p<0.05$). Similarly, [21], compared the effects of eccentric (ECC) and concentric (CON) resistance training on strength and walking speed. There was a significant change on time of contraction ($p<.0001$) and power in the paretic leg (ECC $p<.0001$, CON $p=.03$) from both the CON and ECC groups. However, [1], assessed the effectiveness of strength training on muscles. Strengthening exercises had more impact (65.31%) on manual muscle testing (MMT) of the Gluteus Maximus ($p>0.05$, df = 28) and insignificant (31.32%) on MMT of the ankle plantar flexor and spasticity.

3.2.3 Effects of strength training on balance

Two studies tested dynamic balance and gait abilities by comparing TUG, BBS and 10 MWT [8, 19]. There was a statistical significant difference between these tests with a p-value of $p < 0.05$; $p < 0.0001$ in the experimental group. One study compared the effects of bilateral and lower limb strengthening exercises on balance and walking by testing TUG, BBS and 10MWT [14] Results showed that bilateral limb strengthening exercises effectively promote balance in patients with stroke, showing a significant statistical difference of $p < 0.05$ for functional reach test (FRT) and $p < 0.05$ for Berg Balance Scale (BBS).

3.3 Primary and secondary outcome measures

The 16 included trials had a wide range of outcome measures. Some studies had more than one measure whereas others categorised them into primary and secondary. Functional outcome measures based on walking distance, four trials tested 6 Minute Walk Test using 0.8m/s [8, 12, 18, 19, 25]. For walking speed, six trials tested 10 Meter Walk speed [8, 12, 13, 14, 20], 2 Meter Walk speed [10]. As for sit-to-stand, six trials tested Timed Up and Go (TUG) test [8, 12, 14, 18, 19, 29], one tested sit-to-stand (STS) ability timing [18]. Finally, three studies tested standing balance and reach, using Berg Balance Scale [8, 14, 19] one for standing balance [15] and balance function [19], and SF-36 [12].

Activities of daily living (ADLs) measures included one study that used Instrumental activities of daily living scale (IADL) [20], two used the Functional independence measure (FIM) [1, 12] and two used Barthel index scores [18, 20]. To test for quality of life and health status, one study used the Euro Quality of life (QoL) scale [23], two used a Stroke specific quality of life (SS-QoL) [8, 12], and one a Health Survey questionnaire [12]. Two studies used the Rivermead mobility index (RMI) to test for mobility [8, 12], and the stroke impact scale (SIS) for perceived participation [15]. To monitor an increase in muscle tone, two studies used the Modified Ashworth Scale (MAS) [8, 18]. Finally, to test muscle strength, one study used the Biodex Multi-Joint System 3 dynamometer [18], another used Biodex Isokinetic Dynamometry [23], and the other manual muscle testing (MMT) [1].

3.3 Methodological quality and risk of bias for included studies

Among the appraised studies, majority of them (n=11) were good and scored between 8-11/11, while 5 were moderate with scores between 5-7/11. All the 16 studies included in this review had participants randomly assigned to either the experimental or control group. However, there was no equal distribution of participants to the groups. Out of 16 studies, only 7 had an equal number of participants while 9 studies were unevenly distributed. The methods of randomisation and blinding used in some studies (n=8) had little specification implying that the risk of bias was high [1, 8, 12, 16, 18, 22, 28, 29]. In contrast, studies by [8, 14, 10, 19] used a table of random sampling numbers (SAS SOFTWARE).

Other studies conducted by [15, 21], gave a detailed account of randomisation and blinding using assessor and trial statistician blinding at a ratio of 1:1. One study by [15], used minimisation procedure with stratified randomisation method and research assistants blinding. In some studies there was no bias in allocation of participants because randomisation was by drawing from a sealed opaque envelope container at a ratio of 2:1 and observer blinding to the measurement and allocation was done [23, 25].

3.4 Study setting and country of study

This review included 16 articles whose primary focus was on the effects of strength training on functional gait/walking, strength and balance, and met the criteria. These studies were conducted in 11 countries with the majority from Korea, followed by UK, then USA. Most of these studies (24%, N=4) were conducted in Korea [14, 16, 19, 22]. Two (18%), from United Kingdom [23, 29]. Two (12%) from the United States of America [21, 25].

Continentally, however, seven articles came from Europe [10, 15, 18, 20, 23, 28, 29], seven articles were from Asia [1, 8, 12, 14, 16, 19, 22], two articles came from America [21, 25] and none of these studies came from the African continent.

3.6 Duration of intervention

The duration of the intervention period was between 3 weeks and 6 months in 16 studies. In three studies the training period was 3 weeks [8, 10, 21]. The intervention was for 4 weeks in 6 studies [12, 14, 19, 20, 22, 25]. In three studies [16, 23, 29], the interventions was for 6 weeks. Only one study had a training programme of up to 8 weeks [28]. One study carried out the intervention for 10 weeks [18] and 12 weeks [15]. Another extended the intervention programme to 6 months [1]. Four studies included a post intervention programme ranging from 3-6 weeks [16], 12 weeks [23, 29], and 4 years [18] as follow-ups.

3.6.1 Intensity and frequency of intervention

The intensity ranged from twice to 5 times a week for a minimum of 25 minutes to a maximum of 90 minutes. One study [28], administered exercises for 3 hours per week. In two studies [15, 18], the intervention was administered for 90 minutes and 80% maximum respectively, 2 times in a week. Four studies [16, 21, 22, 25], administered exercises 3 times in a week and one specifically for 25 minutes [25]. Two studies administered exercises 4 times a week for 1 hour [23, 29]. In six studies [8, 10, 12, 14, 19, 20], exercises were performed 5 times a week for 25 minutes [15], 30 minutes [10], 60 minutes [14] and 3 sets per day [12]. One study gave 2-3 sets for an unspecified number of days in a week [1].

Characteristics of included studies

Author & Year	Study design	Participants / Sample size	Age	Time post stroke	Intervention Experimental/ Control	Intensity frequency & duration	Outcome measures
Cooke et al. 2010	RCT	109 E-FST 38 E-CPT+FST36 C- CPT+ CPT 35	>18 years	8 weeks 1-3 WEEKS	C:CPT-Conventional physiotherapy E1: CPT+CPT-sensory stimulation, functional task & quality of movement. Passive movements, active assisted exercises E2:FST+CPT-Conventional physiotherapy & functional strength training- repetitive, progressive resisted exercises & functional tasks (stair climbing, sit-to-stand, walking, transfers, treadmill)	-1hour/4 days / week for 6 weeks (24hours) -12 weeks follow-up	Primary: walking speed (10 meter walk test) Secondary: Walking speed -Modified Rivermead mobility index -Temporal- spatial gait parameters -Euro-QoL -CYBEX NORM isokinetic dynamometer

Table continued…

Port et al. 2012	RCT	250 E-126 C-124	Nil	Not specified	E- circuit training C- usual physiotherapy	-Circuit training 90min/2 times/week for 12wks several work stations	Primary -Mobility domain of stroke impact scale (SIS) Secondary -Standing balance -Self-reported abilities -Gait speed -Walking distance -Stair climbing -Instrumental ADLs -Fatigue, anxiety & depression
Flansbjer et al. 2012	RCT	18 E-11 C-7	66 years, SD 4	69 months	E:Progressive resistance training C:Usual daily activities	2 times/week for 10 weeks 4 years follow-up E: knee flex & Ext 80% 2 times/week/10 weeks	-Modified Ashworth Scale (MAS) -Gait performance (TUG) -Fast Gait speed (FGS) -6MWT -Stroke Impact Scale (SIS) -Muscle strength
Clark & Patten 2013	RCT	34 E-15 C-18	Adults	6-18 months	E:eccentric resistance training (ECC)-paretic limb & gait training C:concentric resistance training (CON)-paretic limb & gait training	3days/week for 3 weeks Gait training-3 days/week for 90 mins -15mins stretching -30mins gait -15 balance -30 treadmill walking	-Walking speed -Strength -Neuromuscular activation
Lee & Kang 2013	RCT	20 E-10 C-10	53.40± 9.71 & 53.86± 10.56		E: isokinetic eccentric resistance exercises -conventional physiotherapy (CPT) 6 weeks Stair climbing up & down C:conventional physiotherapy (CPT) 6 weeks	60 minutes/3 times/week for 6 weeks 3-6 weeks follow-up	-Stair climb up & down -TUG -Gait velocity
Shahid et al. 2013	RCT	30 E-15 C-15	>45yrs Mean age 57 years	90 days	E: strength training exercises -isometric workouts -weight bearing medium progressive exercises -active assisted isometric exercises -free weights & mechanical forces -PNF C:conventional treatment	2-3 sets for 6 months	-Cadence -Manual muscle testing-(MMT) -Spasticity -Instrumental activities of daily living scale (IADL)
Kim et al. 2015	RCT	32 E-16 C-16	61.7 ± 6.1 & 65.2 ± 6.4	6 months	E:Cycling 30 minutes + traditional therapy C:Traditional therapy	5 times/week for 4 weeks	Balance function Berg Balance scale TUG 10MWT
Sen et al. 2015	RCT	50 E-25 C-25 Included 30 healthy subjects	51.3 ± 12.0 & 55.4 ± 10.5	2-8 months	E:concentric isokinetic strengthening C:conventional therapy	5 days/week for 3weeks	-Functional Independence Measure (FIM) -Stroke specific quality of life (SSQoLs) -10MWT 6MWT -Staircase Climbing Test TUG Berg Balance Scale Rivermead Mobility Index (RMI)

Table continued…							
Kerr et al. 2015	RCT	93 E-31CPT+MPT E-30 FST+CPT C-32 CPT	Mean age 68.8	13 weeks	-all participants received conventional therapy (CPT) C: CPT E: CPT + MPT-functional tasks i.e STS, walking & standing E- FST CPT- progressive resistive exercises	1 hr/4 days/week for 6 weeks 3 months follow-up -CPT = 9.2 hrs (SD 6.9) -CPT+ MPT= 7.4 hrs (SD 8.6) -CPT+FST= 8.9 hrs (SD 8.2)	-STS ability -Timing -Symmetry -Co-ordination -Smoothness & knee velocity
Chen et al. 2015	RCT	31	67.1 ± 11.9 & 64.7 ± 13.5	6 months	E:isokinetic training group 3 sets/5 times isokinetic strengthening -knee concentric flexion/ extension -knee eccentric flexion/extension (60°/sec) C:isotonic training group Sets isotonic strengthening/10 repetitions -60° isotonic resistance, isometric flexion -90° extension peak torque, flexion of bilateral knees	3 sets/day, 5 times/week for 4 weeks	-Peak Isometric torque of knee 90° flex -Peak torque knee extension & flexion 60° sec &120°/sec -Short form SF-36 -Health Survey questionnaire -TUG test -Inflammatory Cytokines
Park et al. 2016	RCT	6 E-3 C-3	54.67± 3.45		E: Post-training MVIC Trunk exercises- bridging, curl-up with arms crossed with straight reach & with diagonal, abdominal hallowing, & quadruped exercises C:Pre-training MVIC (maximal voluntary isometric contraction)	times/week for 4 weeks -3 sets	-Gait performance -Gait speed -surface electromyography (sEMG) using BTS FREEEMG 1000 -spatiotemporal gait parameters
Boyne et al. 2016	RCT	18 E- 13 C-5	35-90 years	>6 months	E: HIT; high intensity interval training-30sec treadmill 30-60 C:MCT;medium intensity interval-continuous treadmill walking 45-50%	25min, 3 times/week for 4wks	10 meter walk 6 minute walk Aerobic capacity measure Treadmill gait measures
Druzbicki et al. 2018	RCT	30 E-15 C-15	Nil	30 days subacute	E body weight support treadmill training with biofeedback C body weight support treadmill training without biofeedback conventional rehabilitation i. e Balance & stability exercises, gait	30 min, 5days/week for 3 weeks	Primary: -Gait analysis-spatio-gait parameters -Gait symmetry Secondary: -gait velocity -endurance -mobility
Joen & Hwang, 2018	RCT	20 E-10 UTG C-10 BTG	<65 years	<24 months	E:bilateral therapy (BTG)-strength training for lower paretic (30 mins) & non paretic limbs (20 mins) & passive ROM (10 mins) C:unilateral therapy (UTG)-strength training for paretic lower limb (50 mins), passive ROM (10 mins)	60 mins/5 times/week for 4 weeks	-Functional reach test (FRT) -BBS -TUG -10MWT
Fotiadou et al. 2019	RCT	6 E- 3 C-3	64.42 ± 8.59 years	12-18 months	E: Strength, endurance & flexibility training, neuromuscular activities C: Usual daily activities	3 hourly/week for 8 weeks	Gait kinematics

Table continued…							
Nave et al. 2019	RCT	200 E-105 C-95	18 years	5-45 days Subacute	E:Aerobic, body weight supported -treadmill based physical fitness training -standard rehabilitation therapy C: Relaxation sessions -Standard rehabilitation therapy	25min/5 times/week for 4 weeks	Primary outcomes -Walking speed (10MWT) test -Barthel Index Score Secondary outcomes -6 MWT -Rivermead mobility index -Modified ranking scale

Adverse effects of interventions

Most of the studies included in this review did not report any adverse effects on participants, except in one [20] where a patient fell during circuit training and another was treated for arrhythmias.

4. DISCUSSION

4.1 Strength training approaches

The primary aim of this review was to compare the effects of strength training and conventional therapy on functional gait of stroke patients. All sixteen studies reviewed here demonstrate a range of approaches used to investigate the effects of strength training on functional gait. Several studies investigated approaches such as repetitive and progressive resisted exercises, circuit training, eccentric resistance training, eccentric and concentric isokinetic strengthening exercises, cycling, body weight support treadmill training, high intensive interval training, aerobics, bilateral strength training and endurance training [1, 8, 10, 12, 14, 16, 18, 19, 20, 21, 25, 28]. Another set of studies included interventions like functional tasks as a modality to increase muscle strength [23, 29], circuit training using several workstations [15]. Others looked at more specific trunk exercises such as bridging, curl-up, straight reach, and diagonal abdominal hallowing [22]. These specific interventions might have contributed to improved muscle strength and power, walking speed and functional gait as well as balance because of the workload on the working muscles and the frequency of carrying out these interventions. The comparator modalities also known as conventional therapy or traditional therapy were the usual daily activities, concentric resistance, isotonic training, isometric contraction, and relaxation sessions.

4.2 Strength training on muscle strength and walking speed

A good number of studies in this review endeavored to assess the impact of strength training on muscle power and walking speed in stroke patients. One long term study recorded an exponential increase in muscle power (Isotonic strength; 30-70%, $p<0.001$: Isokinetic strength; 8-87%, $p<0.05$) for subjects in the experimental group using progressive resistance training compared to the control group that used the usual activities of daily living. Probably these positive results were due to the longer follow-up programme (4 years). On average, studies in which muscle strength and walking speed (5 meter- 0.09m/s (0.02) recorded a substantial increase in the experimental group, subjects received strength training 2-3 times per week for not less than 6 months and the level of significance was $p<0.05$ [1, 16, 18, 20, 21]. This suggests that frequency as well as the length of strength training contributes to the increase in muscle strength and walking speed.

Park et al. (2016), on the other hand carried out a trial on 6 subjects to establish the relationship between trunk muscle exercises and gait and muscle function of patients with stroke. Specific gait factors such as walking speed (53.00 ± 5.38), walking cycle (0.40 ± 0.04) and stride length (65.83 ± 5.27) significantly increased ($p<0.05$). Few of the studies included in this review (n=3) combined strength training and conventional or traditional therapy [16, 23, 29] as opposed to only using strength training on the experimental group and conventional therapy on the control group. In spite of this combination, there was an increase in walking speed or gait velocity [16, 23] and sit-to-stand ability [29].

4.3 Strength training and sit-to-stand

On the contrary, [29], conducted a trial on 93 subjects to compare functional strength training (FST) and movement performance therapy (MPT), to improve sit-to-stand in patients with stroke. Patients were randomised across three groups, namely conventional physical therapy (CPT), a combination of CPT and MPT, and CPT and FST, with intervention lasting 1 hour, 4 times a week for 6 weeks. All patients from the three groups improved their sit-to-stand ability, although hip muscle strength, stair up and down time, gait velocity and TUG improved in the experimental group ($p<0.05$). They concluded that neither MPT nor FST added value to CPT in the recovery of sit to stand ability after stroke.

4.4 Strength training on balance

To establish the significance of bilateral lower limb strengthening exercises on balance and walking, [14], isolated 20 stroke subjects and assigned them evenly to unilateral control and bilateral experimental groups. The significant difference of results ($p<0.05$) in the two groups prove that strength training of both lower limbs is critical in attaining substantial walking speed because both the paretic and non-paretic limbs incur muscle weakness in patients with stroke.

4.5 Study strengths and limitations

4.5.1 Study strengths

This review included studies that had clearly defined randomization of participants to the experimental and control groups. The review isolated studies of good quality (n=16) which provided insight to the review process. There was a significant improvement in gait performance, mobility, muscle strength and increased gait/walking speed. The review suggests that strength training is an effective intervention for improvement of gait performance, mobility, muscle strength and increased gait/walking speed.

4.5.2 Study limitations

A number of studies did not report on limitations (n=8). This review analysed the effects of strength training on patients with stroke with particular focus on functional gait and muscle strength. Nevertheless, the studies included in this review typically had a small number of participants, a short duration for intervention and no follow-up programme. Moreover, no studies conducted in Sub-Saharan Africa were available for inclusion in this review hence making it more difficult to generalize conclusions drawn from this review.

5. CONCLUSION

This review aimed at comparing strength training to conventional therapy in improving functional gait in stroke patients. Results from the 16 studies included suggests that progressive resistance training or strength training is the most efficient in improving muscle strength in lower limbs, trunk muscles, gait parameters, and balance of patients with stroke. The statistically significant improvement in muscle strength and subsequent gait performance in patients with stroke after strength training, entails that physiotherapists have to consider including strength training as a suitable intervention in stroke management. Nevertheless, these studies typically had no studies conducted in Africa. Equally, the sample size was small in a number of studies, a short duration for intervention and no follow-up programme. Further research in this area especially in Sub-Saharan Africa is recommended in order to strengthen the evidence base.

Clinical Implication: This review implies that strength training can be used in isolation to improve functional gait and speed, and muscle strength. The dosage of strength training could be 25-90 minutes, between 3-5 sessions per week, for 3 to 24 weeks. This work has demonstrated the impact of lower limb and trunk muscle strengthening among stroke patients at various phases between 2-90 months after stroke.

Acknowledgement: None

Conflict of Interest: None

Source of Funding: None

REFERENCES

1. Shahid, M., Baig, U.A. & Naseem, A. (2013). Effectiveness of strength training in post stroke. Annals, 19(1), 64-69.
2. Wist, S., Clivaz, J. & Sattelmayer, M. (2016). Muscle strengthening for hemiparesis after stroke: A meta-analysis. Annals of Physical & Rehabilitation Medicine, 59, 114-124. http://dx.doi.org/10.1016/j.rehab.2016.02.001
3. Nayak, P., Mahmood, A., Natarajan, M., Hombali, A., Prashanth, G. C. & Solomon, J. M. (2020). Effect of aquatic therapy on balance and gait in stroke survivors: A systematic review and meta-analysis. Journal of Complementary Therapies in Clinical Practice, 39, 1-11. https://doi.org/10.1016/j.ctcp.2020.03.101110
4. Verma, R., Arya, K. N., Sharma, P. & Garg, R. K. (2010). Understanding gait control in post-stroke: Implications for management. Journal of Bodywork & Movement Therapies, 16, 14-21. http://dx.doi.org/10.1016/j.jbmt.2010.12.005
5. Arya, N. K., Pandian, S., Verma, R. & Garg, R. K. (2011). Movement therapy induced neural reorganisation and motor recovery in stroke: A review. Journal of Bodywork & Movement Therapies, 15, 528-537.http://doi.org/10.1016/j.jbmt.2011.01.023
6. Abedi, M., Moghaddam, M. M. & Fallah, D. (2018). A Poincare map based analysis of stroke patients' walking after a rehabilitation by a robot. Journal of Mathematical Biosciences. Retrieved on 6th June, 2020 from http://doi.org/10.1016/j.mbs.2018.03.001
7. Xing, Y., Yang, S-D., Dong, F., Wang, M-M., Feng, Y-S. & Zhang, F. (2018). The beneficial role of early exercise training following stroke and possible mechanisms. Journal of Life Science, 198, 32-37. https://doi.org/10.1016/j.Ifs.2018.02.018
8. Sen, S. B., Demir, S. O., Ekiz, T. & Ozgirgin, N. (2015). Effects of the bilateral isokinetic strengthening training on functional parameters, gait and quality of life in patients with stroke. International Journal of Clinical Experimental Medicine, 8(9), 16871-16879.
9. Sharma, V. & Kaur, J. (2017). Effect of core strengthening with pelvic proprioceptive neuromuscular facilitation on trunk, balance, gait, and function in chronic stroke. Journal of Exercise Rehabilitation, 13(2), 200-205. https://doi.org/10.12965/jer.1734892.446
10. Druzbicki, M., Przysada, G., Guzik, A. et al. (2018). The efficacy of gait training using a body weight support treadmill and visual biofeedback in patients with subacute stroke: A randomized controlled trial. Journal of Biomedical Research International, 2018, 1-10. https://doi.org/10.1155/2018/3812602
11. Zhao, Y., Hao, Z. & Li, J. (2014). Auditory P300 as an indicator in effectiveness of robot-assisted lower limb rehabilitation training among hemiplegic patients after ischemic stroke. Open Journal of Therapy & rehabilitation, 2, 76-85. http://dx.doi.org/10.4236/ojtr.2014.22012
12. Chen, C-L., Chang, K-J., Wu, P-Y., Chi, C-H., Chang, S-T. & Cheng, Y-Y. (2015). Comparison of the effects between isokinetic & isotonic strength training in subacute stroke patients. Journalof Stroke & Cerebrovascular Diseases, 24(6), 1317-1323.

http://dx.doi.org/10.1016/j.jstrokecerebrovasdis.2015.02.002

13. Kilbride, C., Norris, M., Theis, N. & Mohagheghi, A. A. (2013). Action for rehabilitation from neurological injury (ARNI): A pragmatic study of functional training for stroke survivors. Open Journal of Therapy & Rehabilitation, 1(2), 40-51. http://dx.doi.org/10.4236/ojtr.2013.12008
14. Joen, H. J. & Hwang, B. Y. (2018). Effects of bilateral lower limb strengthening exercises on balance and walking in hemiparetic patients after stroke: A randomised controlled trial. Journal of Physical Therapy Science, 30, 277-281. http://creativecommons.org/licenses/by-nc-nd/4.0/
15. Van de Port, I. G. L., Wevers, L. E. G., Lindeman, E. & Kwakkel, G. (2012). Effects of circuit training as alternative to usual physiotherapy after stroke: Randomised controlled trial. British Medical Journal, 344:e2672doi:10.1136/bmj.e2672.
16. Lee, S-B. & Kang, K-Y. (2013). Effects of isokinetic eccentric resistance exercise for the hip joint on functional gait of stroke patients. Journal of Physical Therapy Science, 25, 1177-1179.
17. Matsuyama, A. (2018). Factors associated with the walking ability of hemiplegic stroke patients. Open Journal of Nursing, 8, 14-25. https://doi.org/10.4236/ojn.2018.81002.
18. Flansbjer, U-B., Lexell, J. & Brogardh, C. (2012). Long-term benefits of progressive resistance training in chronic stroke: A 4year follow-up. Journal of Rehabilitation Medicine, 44, 218-221. http://doi.org/10.2340/16501977.0936
19. Kim, S-J., Cho, H-Y., Kim, Y. L. & Lee, S-M. (2015). Effects of stationary cycling exercise on the balance and gait abilities of chronic stroke patients. Journal of Physical Therapy Science, 27, 3529-3531. http://creativecommons.org/licenses/by-nc-nd/3.0/>
20. Nave, A. H., Rackoll, T., Grittner, U., Blasing, H., Gorsler, A., Nabavi, D. G. et al. (2019). Physical fitness training in patients with subacute stroke (PHYS-STROKE): Multicentre randomised controlled, endpoint blinded trial. British Medical Journal. 2019; 366:15101. http://dx.doi.org/10.1136/bmj.15101
21. Clark, D. J. & Patten, C. (2013). Eccentric versus concentric resistance training to enhance neuromuscular activation and walking speed following stroke. Journal of Neurorehabilitation & Neuro Repair, 1-10. http://doi.org/10.1177/1545968312469833
22. Park, B-S., Noh, J-W., Kim, M-Y., Lee, L-K., Yang, S-M., Lee, W-D., Shin, Y-S., Kim, J-H., Lee, J-U., Hwang, B-Y. & Kim, J. (2016). Randomised controlled pilot trial of truncal exercises after stroke to improve gait and muscle activity. Journal of Neuroscience and Medicine, 7, 149-156. http://dx.doi.org/10.4236/nm.2016.74015
23. Cooke, E. V., Tallis, R. C., Clark, A. & Pomeroy, V. M. (2010). Efficacy of functional strength training on restoration of lower-limb motor function early after stroke: Phase I randomized controlled trial. Journal of Neurorehabilitation & Neuro Repair, 24(1), 88-96. http://doi.org/10.1177/1545968309343216
24. Todd, J. S., Shurley, J. P. & Todd, T. C. (2012). Thomas L. DeLorme and the science of progressive resistance exercise. Journal of Strength & conditioning Research, 26(11), 2913-2923. http://doi.org/10.1519/jsc.0b013e31825adcb4
25. Boyne, P., Dunning, K., Carl, D., Gerson, M., Khoury, J., Rockwell, B., Keeton, G., Westover, J., William, A., McCarthy, M. & Kissela, B. (2016). High intensity interval training and moderate continuous training in ambulatory chronic stroke: A feasibility study. Retrieved on 6th June, 2020 from http://doi.org/10.2522/ptj.2015.02.77
26. World Health Organisation (2001). International Classification of Functioning, Disability and Health. Geneva: WHO.
27. Guyatt, G. H., Sackett, D. L. & Cook, D. J. (1994). Users' guides to the medical literature. VI. Howe to use an overview. Evidence-Based Medicine Working Group. JAMA, 272, 1367-1371.

28. Fotiadou, S., Kouroumichakis, I., Besios, T., Papanas, N., Giannakou, E., Gourgoulis, V. & Anngeloussis, N. (2019). Effect of exercise on gait kinematics and kinetics in patients with chronic ischaemic stroke. Open Journal of Therapy and Rehabilitation, 7, 140-150.https://doi.org/10.4236/ojtr.2019.74010
29. Kerr, A., Clark, A., Cooke, E. V., Rowe, P. & Pomeroy, V. M. (2015). Functional strength training and movement performance therapy produce analogous improvement in sit-to-stand early after stroke: Early-phase randomised controlled trial. Journal of Physiotherapy (2016), http://dx.doi.org/10.1016/j.physio. 2015.12.006

How to cite this article: Mwansa MR, Himalowa S, Kunda R. Functional gait of patients with stroke after strength training: a systematic review of randomised controlled trials. *Int J Health Sci Res.* 2021; 11(7):144-158. DOI: *https://doi.org/10.52403/ijhsr.20210721*

******