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Therapeutic exercise methods for improving balance and speed in gait for chronic stroke patients.

A Narrative Literature Review

DEGREE PROGRAMME IN PHYSIOTHERAPY 2023

ABSTRACT

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The aim of this thesis was to shed light on methods for enhancing walking speed and balance in stroke survivors. Conducted as a narrative literature review, the primary research question guiding this exploration was: 'Which therapeutic exercise method is most effective in improving balance and speed for stroke patients?' To address this overarching question, the thesis was organized into chapters, each dedicated to answering specific sub-research questions.

The thesis provides a comprehensive overview and comparison of existing knowledge and research on the subject. Through this narrative literature review, readers can discern relevant therapeutic exercise methods for practical application or informational purposes. To ensure the inclusion of recent and pertinent studies, the inclusion and exclusion criteria were applied to clinical trials conducted from 2005 to 2023.

This review incorporates findings from ten studies focused on investigating the effects of therapeutic exercise methods on walking speed and balance in chronic stroke patients. Upon analyzing and comparing the results of these studies, the thesis concludes that walking-specific therapeutic exercise methods represent task-specific improvements. In contrast to other therapeutic exercise methods that merely show correlations, walking-specific approaches prove to be more effective in enhancing both walking and balance for chronic stroke patients.

Keywords: Chronic, Stroke, Walking, Balance, Rehabilitation, Therapeutic exercise

FOREWORD

There are endless options of therapeutic exercise methods. Then again, there are plenty of research papers that investigate therapeutic exercise methods. These research papers are extremely helpful in showing us therapeutic exercise methods that work for patients who have suffered a stroke. This narrative literature review will compare different therapeutic exercise methods that are good for improving balance and speed in walking for patients or therapists that work with patients who have suffered from stroke. The main research question is: ‘what therapeutic exercise method is best for improving balance and speed in stroke patients?’ To answer this question, the chapters have been divided into sub-research-questions, that will answer the main research question. The predicted outcome of this thesis is that aerobic therapeutic exercise methods will have a positive effect on the walking speed and balance of chronic stroke patients.

CONTENTS

1 INTRODUCTION

A big problem for chronic stroke patients is having trouble with balance. Falling incidents are a high-risk factor for patients with poor balance due to chronic stroke. Moreover, balance is important for one of our most functional activities, walking. A chronic stroke patient has trouble with walking due to poor balance, therefore they cannot walk as fast as a healthy individual according to research from Goh et al (2016). The decrease in balance and walking speed could lead to impairments in activities of daily living or participation problems. This could then lead to numerous other problems for the patient that result in a decay of their physical and mental health (Mansfield et al., 2018). Balance consists of neural and musculoskeletal systems. The muscles of the lower extremities must produce enough force at the right time to create effective balance. To make this work, the neural and musculoskeletal systems of the body must work together harmoniously. Furthermore, muscle strength of the lower extremities and aerobic capacity are correlated with balance performance in patients that suffer from a stroke according to research from Lund et al. (2017). Both aspects could be improved with different therapeutic exercise methods. Clinical tests that evaluate the walking speed of patients with stroke could be used to evaluate the effectiveness of different therapeutic exercise methods. Balance is correlated with walking speed in patients with a stroke, according to research from Britto et al. 2016. These results suggest that the better the balance, the greater the speed and walking ability of the patient is.

2 AIM, OBJECTIVE AND METHOD

The aim of this narrative literature review is to critically evaluate the existing knowledge related to therapeutic exercise methods for improving balance and walking speed in chronic stroke patients. By examining a wide range of studies, comparing results of clinical trials, observational studies, and qualitative research, this review seeks to give the reader an overview of the most recent and relevant research on the topic to find out what the best methods are for improving balance and speed in walking for chronic stroke patients.

The objective of this thesis is to provide insights into methods for improving speed and balance in walking for patients that have suffered a stroke. This thesis will also give the reader an overview of the most relevant research that is currently available on therapeutic exercise methods for improving speed and balance in walking for patients that have suffered a stroke. This can be useful if the reader has limited time to conduct research or to connect practicing clinicians to research about the topic to find out gaps in the current research to e.g., conduct future research.

The method of this thesis is a narrative literature review. The thesis is giving an overview and comparison between current knowledge and research. With this narrative literature review the reader can identify relevant therapeutic exercise methods for application or informational reasons.

3 THESIS PROCESS

Writing a narrative literature review on the topic of improving balance and walking speed for chronic stroke patients involves a systematic plan. The following table provides a structured overview of the key steps in the thesis process for a narrative literature review.

Table 1. Thesis process

Task	Date
Topic selection	01.06.2022 – 15.01.2023
Literature search	15.01.2023 – 25.04.2023
Study selection process	25.04.2023 – 15.06.2023
Thesis writing and structuring	15.06.2023 – 20.10.2023
Thesis finalization	20.10.2023 – 15.11.2023
Thesis presentation	22.11.2023

4 STROKE

4.1 Definition of stroke

The World Health Organization categorizes stroke as an incident characterized by clinical signs that result in a disruption of cerebral function. Another commonly employed term for stroke is cerebrovascular accident. The symptoms persist for a duration of 24 hours or more and can result in life-altering consequences, including the risk of mortality. The origin of a stroke is vascular, falling into two main types: ischemic stroke and hemorrhagic stroke (Tadi et al., 2023).

4.1.1 Ischemic stroke

With about 87% the Ischemic stroke is the most common form of cerebrovascular accident. It is characterized by a blockage in a blood vessel. This blockage, often referred to as embolism or thrombus, causes a shortage of blood supply to particular brain regions. When the blood supply is not able to reach a particular brain region this prevents an efficient supply of nutrients and oxygen, which can result in brain cells to die. Possible consequences can be clinical signs such as long-term brain damage, disability or even death (Adams et al., 1993).

4.1.2 Intracerebral Haemorrhagic stroke

On the other hand, hemorrhagic strokes occur when a blood vessel ruptures, leading to blood leakage into the intracranial cavity. These strokes can be categorized into Intracerebral Hemorrhage and Subarachnoid Hemorrhage, as outlined by the Stroke Association (2019).

Intracerebral Hemorrhagic stroke stands as the second most prevalent form of stroke following Ischemic stroke. Locations commonly associated with intracerebral hemorrhages include the basal ganglia, cerebral lobes, cerebellum, or pons. Additionally, regions such as the midbrain, putamen, or other parts of the brain stem may also be susceptible to experiencing Intracerebral Hemorrhage (Unnithan, 2023).

4.1.3 Subarachnoid Haemorrhage stroke

Only 5% of all strokes are caused by Subarachnoid Haemorrhage. Subarachnoid Haemorrhage is a bleeding between the arachnoid and pia mater of the brain. The Arachnoid and Pia Mater are layers that cover the surface of the brain. They provide the brain with protection and the brain receives blood supply from numerous blood vessels that pass through this layer. The bleeding in the subarachnoid space is a result of a ruptured aneurysm or head trauma. (Shafique, 2023)

4.1.4 Clinical signs and symptoms stroke

Early symptoms of brain ischemia can include walking difficulties and light-headedness, difficulty with one or both eyes' vision, numbness, or weakness, especially on one side of the body, in the arm, leg, or face. It is important to seek immediate medical attention when experiencing one of these symptoms. The longer a person waits with treating a stroke the more brain cells die. Stroke causes brain ischemia. Brain ischemia is a term for lack of blood and therefore oxygen and nutrients to the brain. (DeSai, 2023) This results in a number of disabilities depending on the location of the stroke. Impaired speech, limited motor function, spasticity, weakness, or paralysis of limbs on one side of the body, trouble gripping or holding objects, and a slowed rate of communication are the most typical forms of disability following a stroke. A physiotherapeutic rehabilitation plan with therapeutic exercise methods could be implemented to help reduce these disabilities. (Luengo-Fernandez et al., 2013)

4.2 How stroke impairs balance and speed in walking

Post-stroke, walking function is frequently impacted, with Mansfield et al. (2018) highlighting that 80% of individuals experience some form of walking dysfunction three months after a stroke. This underscores the significance of walking function as a crucial marker for overall stroke recovery. Clinicians often utilize walking speed as a key metric to assess walking capacity, emphasizing the importance of focusing on walking as a rehabilitation goal for chronic stroke patients, as indicated by Mansfield et al. (2018).

Hemiparesis, a prevalent symptom following a stroke, manifests as one-sided muscle weakness, disrupting the natural walking pattern. To compensate for this, chronic stroke patients with hemiparesis tend to exert more weight on their nonparetic leg to maintain balance while walking. This adjustment, however, results in a decrease in both speed and balance during walking (De Sousa Britto et al., 2016). Table 1 provides an overview of common clinical tests employed to evaluate the ability of balance and walking speed in chronic stroke patients.

Table 2. Clinical tests to evaluate balance and walking speed in chronic stroke patients.

Outcome measure	Clinical test		
Balance	Berg Balance Scale	Functional Reach Test	Biodex Balance System
Walking speed	Timed Up and Go Test	2-, 6-& 10-Meter Walk Tests	GAITRite System

5 REGULATION OF BALANCE AND SPEED IN THE HUMAN BODY

5.1 Systems in the body for balance and gait speed

Balancing the human body is an intricate process that relies on the visual, vestibular, and peripheral nervous systems. The nervous system integrates sensory feedback from these systems to construct an internal model of the body's orientation, motion, and connection to the external environment—a process termed postural control (De Sousa Britto et al., 2016). Postural control is essential for maintaining dynamic postures, such as those involved in walking, and is broadly defined as the act of sustaining, restoring, or achieving balance during any activity or posture (Pollock et al., 2000).

Gait, defined as an individual's manner of walking, serves as a critical marker for overall stroke recovery. Clinicians often use walking speed as a comprehensive measure of walking capacity (Mansfield et al., 2018). Understanding the key muscles contributing to increased walking speed is pivotal for enhancing this aspect of walking function. The musculus gluteus maximus, musculus gluteus medius, musculus quadriceps, musculus hamstrings, musculus gastrocnemius, and musculus soleus play primary roles in supporting and advancing walking at all speeds. Any limitations in motor function, spasticity, weakness, or paralysis experienced by chronic stroke patients can adversely impact these muscles and, consequently, their ability to walk effectively (Liu, 2008).

5.1.1 Vestibular system

The vestibular system is a group of neural pathways that partly helps us with maintaining our balance. The vestibular system is located in the ear at the petrous temporal bone. It is a bony labyrinth filled with fluid, which is often referred to as “snail shaped” (Casale, 2023b). Neural pathways connect from the vestibular system to the brain. The brain reacts to afferent input from the vestibular system in the ear to produce efferent feedback on our balance.
The way the vestibular system helps us with our balance is by stabilizing eyesight as the head moves in relation to the body and stabilizing head movement, which helps to stabilize the vision. It provides a sense of autonomy and activates and modulates postural reflexes that help maintain postural control (MacKinnon, 2018).

5.1.2 Visual system

The visual system picks up information about what is being seen through the retina. Information about object contrast, brightness, size, distance to the eye and spatial frequency. This information is being transferred from the eyes through the visual pathway to the visual cortex in the brain, which is located in the occipital lobe. From the retina in the eyes until the visual cortex in the occipital lobe, the information travels through the retina, optic nerves, optic chiasm, optic tracts, lateral geniculate bodies, optic radiations, and visual cortex. Together this makes the visual pathway (Mehra, 2023). The pathway is an important piece of the central nervous system. The visual system uses this information to give feedback to the central nervous system of moving elements of the environment. With the help of this knowledge, planned actions and balance adjustments can be planned and carried out (MacKinnon, 2018).

5.1.3 Peripheral nervous system

The peripheral nervous system comprises nerves extending from the brain and spinal cord, serving as a vital link between the Central Nervous System (CNS) and various body parts. This connection facilitates the transmission of information related to postural control from different areas of the body to the brain (Hubbard, 2012b). Essential contributors to postural control include Muscle spindles, Golgi tendon organs, Joint receptors, and Cutaneous receptors, working in concert with the visual and vestibular systems (MacKinnon, 2018).

Muscle spindles, found in skeletal muscle bodies, act as stretch receptors primarily gauging changes in muscle length. Via afferent nerve fibers, these spindles relay information to the CNS, regulating balance through responses to alterations in muscle length, such as the stretch reflex (Macefield & Knellwolf, 2018). In contrast, Golgi tendon organs detect tension rather than stretch, conveying afferent information to the CNS when muscle contraction affects the antagonist muscle or the contracting muscle itself. The CNS, in turn, responds with efferent impulses to contract or relax the muscle, viewing the tendon organ as a tension receptor rather than a stretch receptor (Blumer, 2010).

Joint receptors activate when a joint reaches its anatomical limit, residing within the joint capsule and transmitting information through afferent nerve fibers to the brain. This activation occurs as a response to surrounding muscles contracting or stretching, influencing postural control (Proske, 2023).

Cutaneous receptors, integral to the somatosensory system, are sensory receptors in the dermis and epidermis layers of the skin. Nociceptors (pain), thermoreceptors (temperature), and mechanoreceptors (pressure) are examples of cutaneous receptors, contributing to the perception of touch, temperature, body position, and pain (Purves, 2001).

The afferent information transmitted from these systems to the brain collectively forms proprioception. Balance and proprioception are closely intertwined, with proprioceptive information crucial for movement control. Proprioception enables normal bodily function during movement and balance maintenance, encompassing the ability to sense forces acting on the body, as well as the position and motion of joints in space (Ferlinc et al., 2019).

6 THESIS METHOD

6.1 Inclusion and exclusion criteria

The type of studies used in this narrative literature review are clinical trials that have been conducted in the past eighteen years, 2005 until January 2023. The type of outcome measures used in the studies that are included need to be clinical tests that have an evaluating purpose, so that the speed and balance in gait can be compared before and after the applied intervention method. Therefore, in this narrative literature review therapeutic exercise methods will be used as the intervention. The inclusion and exclusion criteria for participants in the chosen studies for this narrative literature review are shown in Table 2 and in Table 3.

Table 3. Inclusion criteria.

Number	Inclusion criteria
1	The patients need to have the cognitive ability to comprehend and follow simple instructions and participate in physical therapy treatments.
2	The patients in the studies need to be adults between 18 and 80 years old.
3	The stroke must have occurred more than six months prior to the studies.
4	The stroke patients in the studies must have difficulty with speed and or balance in gait.

Table 4. Exclusion criteria.

Number	Exclusion criteria
1	The patient cannot walk at least a minimum of 10 meters with assistance of a person or with the help of assistive aids.
2	The patients have orthopaedic problems or comorbidities involving the lower extremities that would affect the gait.
3	The patients have a history of other neurological diseases or previous stroke.

6.2 Overview of literature

The inclusion and exclusion criteria have been applied to clinical trials that have been conducted between 2005 and 2023. Ten studies were found for this narrative literature review thesis. These studies research the effects of therapeutic exercise methods on walking speed and balance for chronic stroke patients. In Table 3 an overview can be found of the chosen literature.

Table 5. Overview of literature.

	Study	Titel	Publishing paper	Outcome measures
1	Zhu et al. (2015c)	Hydrotherapy vs. conventional land-based exercise for improving walking and balance after stroke: a randomized controlled trial.	*Clinical Rehabilitation*, *30*(6), 587–593.	*Berg Balance Scale, Functional reach test, 2MWT, Timed Up and Go Test.*
2	Lund et al. (2017)	Balance and walking performance are improved after resistance and aerobic training in persons with chronic stroke.	*Disability and Rehabilitation*, *40*(20), 2408–2415.	*Berg Balance Scale.*
3	Luft et al. (2008)	Treadmill Exercise Activates Subcortical Neural Networks and Improves Walking After Stroke.	*Stroke*, *39*(12), 3341–3350.	*10MWT, 6MWT.*
4	Lee et al. (2017)	Effects of different heel-raise-lower exercise interventions on the strength of plantarflexion, balance, and gait parameters in stroke survivors.	*Physiotherapy Theory and Practice*	*Manual muscle test, Biodex Balance System, GAITRite system.*
5	Lee et al. (2018)	Effects of active vibration exercise using a Flexi-Bar on balance and gait in patients with chronic stroke.	*Journal of Physical Therapy Science*, *30*(6), 832–834.	*Berg Balance Scale, Functional Reach Test, 10MWT, Timed Up and Go Test.*

6	Yang et al. (2007)	Dual-Task Exercise Improves Walking Ability in Chronic Stroke: A Randomized Controlled Trial.	*Archives of Physical Medicine and Rehabilitation*, *88*(10), 1236–1240.	*GAITRite system.*
7	Linder et al. (2021)	Forced and Voluntary Aerobic Cycling Interventions Improve Walking Capacity in Individuals with Chronic Stroke.	Archives of Physical Medicine and Rehabilitation, 102(1), 1–8.	6MWT.
8	Choi et al. (2020)	Effects of Trunk Stabilization Exercise While Wearing a Pelvic Compression Belt on Walking and Balancing Abilities in Patients with Stroke.	*American Journal of Physical Medicine & Rehabilitation* 99(11):p 1048-1055	*P*ostural Assessment Scale for Stroke, Timed Up and Go,
9	Aguiar et al. (2018)	Effects of aerobic training on physical activity in people with stroke: protocol for a randomized controlled trial.	*Trials*, *19*	*6MWT, Shuttle-walk test, Patient Health Questionnaires PHQ-2 and PHQ-9, Stroke impact scale, Stroke-Specific Quality of Life Scale.*
10	Peurala et al. (2005)	The Effectiveness of Body Weight-Supported Gait Training and Floor Walking in Patients with Chronic Stroke	*Archives of Physical Medicine and Rehabilitation*, *86*(8), 1557–1564.	*10MWT, 6MWT, Lower-limb spasticity and muscle force, postural sway tests, Modified Motor Assessment Scale.*

6.3 Limitations

There are limitations to finding the most efficient therapeutic exercise method(s) for balance and speed in walking for chronic stroke patients through a narrative literature review. To have a valid review, the inclusion and exclusion criteria of the compared studies need to match. While the limited range of studies may introduce challenges in terms of reach, it serves to enhance the validity of the results. The age of the participants in the included studies makes a difference because how participants react to therapeutic exercise interventions depends on their age. Younger participants tend to improve faster and recover quicker compared to older participants. Due to changes that come with age our ability to learn new skills and recover from physical activity gets worse. (Fernandes et al., 2021). Some studies use different timelines for therapy. While one study might use three weeks (Peurala et al., 2005b), another study might use twelve (Aguiar et al., 2018a). The duration of an applied therapeutic exercise method makes a big difference in the results. Due to the differences in timelines, it can be hard to say for a fact, which method would be a better option long term for the chronic stroke patient to improve balance and speed in walking.

6.3.1 Evidence Based Practice (EBP)

When conducting a rehabilitation in practice, the three EBP (Evidence based practice) methods are to be considered by physiotherapists before taking a decision in the physiotherapy methods. (Sackett et al., 2007). In the first EBP method, which is about evidence, healthcare professionals analyse the best evidence available to use in their therapy. This narrative literature review is part of this EBP method. Patients experiencing a stroke each have their own set of symptoms and characteristics, meaning every patient is unique. Not only in their symptoms but also their preferences as a person and patient. Therefore, the second EBP method, patient preferences, must be considered before deciding in the rehabilitation of a chronic stroke patient. When the most efficient therapeutic exercise method for balance and speed in walking does not fit into the preferences of what the patient wants. Then another method must be considered by the physiotherapist. Clinical experience of the therapist is the third EBP method. This is the professional opinion of the therapist based on their clinical experience of their career. This thesis is only one of the three EBP methods that is necessary for a successful physiotherapy treatment. Having all the EBP methods would be too wide of a scope and too time constraint for this thesis. For a full EBP treatment this thesis that aims to show the best available evidence is not enough. The clinical experience and patient values must be considered as well. (Jewell, 2014).

6.4 Search strategy

Three online databases (Cochrane.org, pedro.org.au, and pubmed.ncbi.nlm.nih.gov) were used to search for potential studies with a keyword-based search style. The following search terms were used: Exercise OR physiotherapy AND stroke. With the use of these search terms twenty-five potential studies were found. Out of those studies, ten studies have been included. The other 15 studies did not fit the inclusion criteria and were thereby excluded from this narrative literature review.

7 DIFFERENT TYPES OF THERAPEUTIC EXERCISE METHODS FOR STROKE PATIENTS

7.1 Hydrotherapy

In a study conducted by Zhu et al. (2015d), hydrotherapy was systematically compared to conventional land-based exercise through a randomized controlled trial. Following baseline assessments, participants were randomly assigned to two equally sized therapy groups. One group engaged in hydrotherapy sessions for four weeks, while the other group participated in conventional land-based exercises for the same duration. The land-based exercises encompassed stretching, trunk mobility exercises, treadmill training, and strengthening exercises. On the aquatic front, exercises included stretching, strengthening, balance/coordination exercises, and aquatic treadmill exercises.

Both groups adhered to a regimen of 45-minute sessions conducted five days a week. Hydrotherapy sessions were executed on a water treadmill, specifically the Ferno Aquagaiter Underwater Treadmill, within a therapy pool maintained at temperatures between 34°C and 36°C, while the air temperature stood at 24°C. The choice of water temperature, ranging from 33°C to 34°C, aimed to elevate skin temperature, expand blood vessels, increase blood supply, accelerate muscle relaxation, decrease sensitivity to pain or muscular spasm, and enhance balance function, as per findings by Duffield et al. (1983).

It is noteworthy that aquatic exercise, as employed in this study, has demonstrated significant improvements in motor function, static, and dynamic balance among individuals who have experienced a stroke.

7.1.1 Measurement tools

After four weeks of therapy the Berg Balance Scale, functional reach test, 2-minute walk test, and the Timed Up and Go Test were conducted to evaluate the participants on progress in walking and balance. These tests were also conducted before starting the therapy session to find out the baseline of the participants.

7.1.2 Results

The findings of this study reveal that over a four-week program, hydrotherapy exercises demonstrated greater improvements in walking and balance among chronic stroke patients compared to conventional land-based exercises. Specifically, the results from the Functional Reach Test and the 2-Minute Walk Test indicated higher enhancements in balance and walking within the hydrotherapy group. However, these differences in improvements were not evident in the Berg Balance Scale and the Timed Up and Go Test.

7.2 Resistance and aerobic training

In a study conducted by Lund et al. (2017b), a randomized controlled trial explores the impact of resistance and aerobic training on balance and walking. The terms "aerobic" and "resistance" training are broad, and to specify the training methods, the study employs a cycling ergometer, resistance training for the lower extremities, and sham training for the upper extremities. Participants are then categorized into three groups, each assigned to one of these distinct resistance and aerobic training methods.

7.2.1 Measurement tools

Before starting the 12-week therapy, the baseline of the participants was measured. The measurement tools were the Berg Balance Scale, peak oxygen uptake, isometric knee extensor strength, maximal gait speed, and the 6-minute walk test. The participants exercised three days a week in the twelve-week period. After finishing the therapy, the same measurement tools were used again with an evaluative purpose.

7.2.2 Results

All three groups improved balance, maximal gait speed, and the 6-minute walk distance. Cycling ergometer, resistance training of the lower extremities and sham training of the upper extremities does improve balance and walking performance. However, improved balance does not necessarily mean that walking performance is improved as well according to research from Lund et al, 2017b.

7.3 Treadmill exercise

In this study by Luft et al. (2008b). the effects of treadmill exercise on walking are being investigated through a randomized controlled trial. The participants did three 40-minute exercise sessions every week at an aerobic intensity of 60% of heart rate reserve for a therapy duration of 6 months.

7.3.1 Measurement tools

Before the starting the therapy, the baseline of the participants was perceived by use of clinical tests. These tests have been used again in an evaluative manner after the therapy. The used tests are peak effort treadmill-walking velocity, overground walking velocity during the 6-minute walking test and the 10-minute walking test. Cardiovascular fitness, the effects of treadmill exercise on brain activation and gait-recovery were also assessed.

7.3.2 Results

The findings indicate that treadmill exercise enhances walking abilities, fitness levels, and recruits midbrain circuits in the cerebellum. These cerebellar recruitments are linked to improved walking performance. The results underscore the effectiveness of treadmill rehabilitation in fostering gait recovery among stroke survivors with prolonged mobility issues. Additionally, the study suggests the presence of neuroplastic mechanisms, hinting that these approaches may be refined for even more favorable outcomes, as discussed in research by Luft et al. (2008b).

7.4 Heel-raise-lower exercise interventions

In the investigation conducted by Olney et al. (1994), the study explores the effects of various heel-raise-lower exercise interventions on balance and gait. Heel-raise-lower exercises are commonly employed to enhance the strength and power of ankle plantar flexors. Weakness in these muscles can impede the maximal plantarflexion movement necessary for effective walking. Notably, the ankle plays a crucial role in functional independence for stroke patients (Caillet et al., 2003). Strengthening ankle muscles in stroke patients has been associated with positive effects on gait, leading to an increase in gait speed (Ng & Hui-Chan, 2005). This exercise, requiring no equipment and easily performed at home, involves both eccentric and concentric contractions of the calf muscles. Participants engaged in 100 repetitions per day for five days a week over a therapy period of six weeks.

The study categorized participants into two groups: the first performed heel raise-lower exercises with the forefoot on a block, and the second group performed the exercises with the forefoot on the ground. This comparative approach aimed to assess and contrast the outcomes of the two variations of the exercises.

7.4.1 Measurement tools

Before the six-week therapy and after the six weeks certain clinical tests were performed. To set a baseline for the participants and to evaluate the effectiveness and compare which heel-raise-lower variant had the most results. The strength of the plantar flexors, static/dynamix balance, and gait were measured using manual muscle testing, a biodex balance system and the GAITRite system.

7.4.2 Results

Following six weeks of intervention, there was a significant increase in the strength of plantar flexors in both groups. Specifically, the heel raise-lower with the forefoot on a block exhibited a 34% increase in strength, while the heel raise-lower with the forefoot on the floor showed a 21% increase. Crucially, within the scope of this review, both groups demonstrated a notable improvement in static and dynamic balance, along with an increase in gait speed, as highlighted in the study by S. H. Lee et al. (2017b).

7.5 Active vibration exercise using a Flexi-Bar

In the study conducted by D. Lee & Han (2018a), the investigation focuses on the effects of active vibration exercise using a Flexi-Bar on balance and gait. The therapy spanned four weeks, with sessions lasting 20 minutes each day for five days a week. The Flexi-Bar, a 1,520 mm long and 719 g weighing stick, generates approximately 5-Hz vibrations when held at the middle handle and shaken. The stick's design, featuring a 17.9 cm long rubber handle in the middle and heavier rubber ends, facilitates this vibration.

Participants engaged in an up-and-down vibration exercise while standing with the Flexi-Bar, aiming to activate core muscles in the deep part of the trunk. Notably, prior research by Ki-Mai and Joong-San (2015) demonstrated that the Flexi-Bar exercise improved balance in football players. The application of the Flexi-Bar exercise to chronic stroke patients effectively enhanced trunk muscle strength, balance, and postural control, as revealed in the study by S. Lee et al. (2016). This highlights the potential of the Flexi-Bar exercise as a therapeutic method for improving outcomes in chronic stroke patients.

7.5.1 Measurement tools

Before commencing the therapy, baseline assessments were conducted for all participants. These assessments included the Berg Balance Scale and Functional Reach Test for measuring balance, as well as the 10-meter Walk Test and Timed Up and Go Test to assess walking speed. Following the therapy period, the same battery of tests was administered to evaluate the participants' balance and walking speed.

7.5.2 Results

Before initiating the therapy, all participants underwent baseline assessments. These evaluations comprised the Berg Balance Scale and Functional Reach Test for measuring balance, along with the 10-meter Walk Test and Timed Up and Go Test to assess walking speed. Subsequent to the therapy period, the same set of tests was administered to gauge the participants' balance and walking speed.

7.6 Dual-task Exercise

In the study led by Y. R. Yang et al. (2007), the investigation delves into the effects of a dual-task-based exercise program on walking ability through a single-blind randomized controlled trial. Participants engaged in a 4-week ball exercise program, involving sessions three times a week, each lasting 30 minutes. The therapeutic exercise sessions centered around the concept of dual-task training, where participants performed walking activities while concurrently engaging with one or two balls.

Various therapy balls with diameters of 45, 55, 85, and 95 cm, along with a basketball, were utilized. The exercises encompassed walking while holding one or two balls in each hand, walking while bouncing one ball with one or both hands, walking while simultaneously bouncing a ball with one hand and holding another, and walking while holding one ball and simultaneously kicking another basketball into a net. Participants also practiced walking while simultaneously kicking a basketball into a net and bouncing a ball with both hands.

To enhance walking conditions, participants practiced walking in different directions, including forward, backward, in a circle, and in an S-shape. The exercise routine aimed to challenge walking by simultaneously controlling one or two balls, thus creating a dual-task environment. The dual-task-based exercise program, designed to improve walking ability, was evaluated to understand its impact on the subjects' ability to walk after experiencing a chronic stroke.

7.6.1 Measurement tools

The results were measured using a machine called the GAITRite. (Menz et al., 2004) The GAITRite system measures time and distance on an electronic pathway. The information comes into a computer. The pathway has 6 sensor pads. The GAITRite pathway was 10 meters and measured the walking ability of the participants. (Bilney et al., 2003) This was done before the 4-week exercise program to establish the baseline of the participants as well as after the exercise program to measure the improvements.

7.6.2 Results

The results show that the ball-dual-task exercise training had positive effects on improving gait performance of the participants. These results have been measured by the GAITRite machine four weeks after the exercise program.

7.7 Forced and Voluntary Aerobic Cycling

In the research conducted by Linder et al. (2021b), the study explores the impacts of both forced and voluntary aerobic cycling interventions on the walking capacity of chronic stroke patients. The therapeutic sessions took place three times a week over a total therapy duration of 8 weeks. Each session, lasting 45 minutes, incorporated a 5-minute warm-up and a 5-minute cool down. The exercise sessions were conducted using stationary bicycles.

7.7.1 Measurement tools

The baseline of the participants, and possible improvements of walking capacity tested at the end of the treatment have been measured with the 6-minute walking test.

7.7.2 Results

The findings from the 6-minute walking test revealed significant improvements among participants following the 8-week aerobic cycling therapy. This suggests that the prescribed aerobic cycling intervention, lasting 8 weeks and set at 60% to 80% of heart rate reserve (the difference between the maximum heart rate and the resting heart rate), coupled with a moderate to high cadence and resistance, resulted in noteworthy enhancements in the walking ability of chronic stroke patients.

7.8 Effects of Trunk Stabilization Exercise While Wearing a Pelvic Compression Belt

In the study conducted by Y. Choi et al. (2020), the investigation focused on examining the effects of trunk stabilization exercise while wearing a pelvic compression belt on walking and balance in chronic stroke patients. This was carried out through an assessor-blinded, preliminary, randomized, controlled study. The therapy spanned a duration of 6 weeks, with sessions held five days a week, each lasting 60 minutes.

7.8.1 Measurement tools

Clinical tests were performed just before the therapy program started. to find out the baseline of the participants and sometime after the 6-week therapy program to evaluate the effectiveness of the used therapeutic exercise method. The main clinical tests that were used are the Postural Assessment Scale for Stroke and the Timed Up-and-Go test.

7.8.2 Results

The results of the study indicated that incorporating a pelvic compression belt while engaging in trunk stability exercises led to significant improvements in both balance and walking ability. Interestingly, wearing the compression belt on the paretic side appeared to yield even more favorable outcomes compared to wearing it on the non-paretic side or not wearing the belt at all. The participants positioned the compression belt just below the anterior superior iliac spine, ensuring a snug fit without causing discomfort or pain.

7.9 Aerobic training (walking)

In this study by Fini et al, (2014) the effects of aerobic training on walking and balance in people with chronic stroke was investigated through a randomized controlled trial. The aerobic activity in this method is walking while the participants maintained a specific heart rate reserve. The study had two groups. The first group maintained a heart rate reserve between 60-80% and the second group had to stay under 40% of their heart rate reserve.

7.9.1 Measurement tools

Heart rate during the therapy sessions was measured using a physical activity meter, the multi-sensor SenseWear Mini, as outlined in the study by Reece et al. (2015). Both groups underwent 40-minute therapy sessions, three times a week, for a total therapy duration of 12 weeks. Baseline measurements of participants were conducted using several clinical tests, including the Six-Minute Walk Test, patient health questionnaires PHQ-2 and PHQ-9, Stroke-Specific Quality of Life Scale, and Stroke Impact Scale. These clinical tests were repeated after the 12-week therapy period for evaluative purposes.

7.9.2 Results

The outcomes indicate that both groups demonstrated significant improvements in walking speed as assessed by the 6-Minute Walking Test. Notably, the group maintaining a heart rate reserve between 60-80% exhibited greater improvements compared to the group instructed to stay under 40% of their heart rate reserve, as reported in the study by Aguiar et al. (2018a).

7.10 Body Weight-Supported Gait Training and Floor Walking

In this study by Peurala et al, (2005b) the effects of body weight-supported gait training and floor walking on balance and walking in chronic stroke patients is being investigated through a randomized controlled trial. The total duration of the therapy was three weeks. The participants were divided into three groups. Group 1 performed gait training with functional electric stimulation. Group 2 performed gait training without functional electric stimulation. Group 3 performed overground walking. During these three weeks the participants had 15 therapeutic exercise sessions. The duration of the sessions was 20 minutes.

7.10.1 Measurement tools

Before starting the three weeks the baseline of the participants was measured with the following clinical tests: Ten-meter walk test, six-minute walk test, lower-limb spasticity and muscle force, postural sway tests, Modified Motor Assessment Scale, and FIM instrument scores. These clinical tests were also performed after the 3-week therapy session to find out if the participants had improved in the clinical tests. A 6-month follow up was done as well. A physiotherapist performed the clinical tests again to see if there were any differences in balance and walking speed 6-months after the therapeutic exercise rehabilitation. Groups 1 and 2 performed the gait training in an electromechanical gait trainer. Group 1 with body weight support and group 2 without.

7.10.2 Results

The body weight-supported gait training and walking exercise training program group participants had significant improvements in gait after the 3-week therapeutic exercise rehabilitation. The motor abilities, gait speed, dynamic balance and motor task performance had all improved according to the results of the clinical tests. In the results of the 6-month follow-up the improvements remained.

8 RESULTS

In the investigation conducted by Zhu et al. (2015d), a comparative analysis between hydrotherapy and conventional land-based exercises was undertaken. After a four-week treatment period, both groups exhibited significant improvements; nevertheless, the hydrotherapy group demonstrated notably higher improvements in the functional reach test and 2-minute walk test.

Lund et al. (2017b) delved into a 12-week exercise program, comparing cycling ergometer, resistance training of the lower extremities, and sham training of the upper extremities. The results revealed that all three groups experienced enhanced balance, maximal gait speed, and the 6-minute walk distance.

The study by Luft et al. (2008b) explored the effects of a 6-month treadmill exercise program on walking. Findings indicated that treadmill exercise led to improvements in walking, fitness, and the recruitment of midbrain circuits in the cerebellum, highlighting its association with enhanced walking capabilities.

S. H. Lee et al.'s investigation (2017b) centered on different heel-raise-lower exercise interventions and their effects on balance and walking. After six weeks, dynamic balance and gait speed significantly increased according to results obtained from the biodex balance system and the GAITRite system.

D. Lee & Han's study (2018a) focused on a 4-week active vibration exercise program using a Flexi-Bar to assess its impact on balance and gait in stroke patients. The outcomes indicated that active vibration exercise significantly improved balance and walking speed, as evaluated by the Berg Balance Scale, Functional Reach test, and the Timed Up and Go Test.

Y. R. Yang et al. (2007) investigated the effects of a dual task walking exercise program on walking and balance for chronic stroke patients. The 4-week dual task walking exercise program demonstrated positive effects on improving gait performance, as measured by the GAITRite machine four weeks after the exercise program.

In the study by Linder et al. (2021b), forced and voluntary aerobic cycling interventions were examined for their effects on the balance and walking capacity of chronic stroke patients. Following an 8-week therapy duration, the 6-minute walking test was conducted, revealing significant improvement among participants.

Choi et al. (2020) explored the effects of trunk stabilization exercise while wearing a pelvic compression belt on walking and balance in chronic stroke patients during a 6-week therapy period. The study's results emphasized that wearing a pelvic compression belt during trunk stability exercises significantly improved balance and walking ability.

Aguiar et al. (2018a) investigated the effects of a 12-week aerobic training program on walking and balance in individuals with chronic stroke. Notably, both groups demonstrated improvements in walking speed in the 6-Minute Walking Test, with the group maintaining a heart rate reserve between 60-80% showing the most significant enhancements.

Lastly, Peurala et al. (2005b) examined the effects of body weight-supported gait training and walking on balance and walking in chronic stroke patients within a 3-week therapeutic exercise rehabilitation program. The body weight-supported gait training and walking exercise program group exhibited significant improvements in gait speed, dynamic balance, and motor task performance.

9 CONCLUSION

Based on this narrative literature review the walking specific therapeutic exercise methods have shown to be more effective in improving walking and balance for chronic stroke patients compared to the other therapeutic exercise methods. The three out of ten therapeutic exercise methods that showed the highest improvements included walking as the main therapeutic exercise. Meaning that specific therapeutic exercise methods, such as walking are designed for particular tasks, leading to targeted improvements. This is in contrast to the other therapeutic exercise methods, which are merely associated with outcomes rather than directly addressing task-specific goals.

10 DISCUSSION

The central inquiry driving this thesis revolves around identifying the most effective therapeutic exercise method for enhancing balance and walking speed in stroke patients. The anticipated outcome positioned aerobic and resistance training methods as the frontrunners in yielding substantial improvements for chronic stroke patients. This expectation stemmed from the integral relationship between balance, proprioception, and walking, where training these components was anticipated to yield more substantial improvements compared to methods solely focusing on walking.

One aerobic and resistance training method explored was presented in a study by Y. Choi et al. (2020), wherein participants wore a compression belt during trunk stabilization exercises. Intriguingly, wearing the compression belt on the paretic side demonstrated superior results, suggesting a potential avenue for enhancing therapeutic outcomes in aerobic training.

Additionally, the study by Lund et al. (2017b) investigated the effectiveness of cycling ergometer, resistance training of the lower extremities, and sham training of the upper extremities as resistance and aerobic training methods. Although these methods improved balance and walking speed, they did not necessarily translate to functional improvements in chronic stroke patients.

Hydrotherapy, as explored in a 4-week rehabilitation program by Zhu et al. (2015d), emerged as a potent intervention for improving walking speed and balance. However, the feasibility of hydrotherapy may be compromised by patient preferences, highlighting the importance of individualized approaches in therapeutic planning.

Ankle-related interventions were also examined, acknowledging the pivotal role of the ankle in walking and the potential positive impact of strengthening ankle muscles on gait speed. Despite this, task-based therapeutic exercise rehabilitation programs, particularly walking methods, demonstrated greater effectiveness in improving walking speed and balance.

Walking, a common therapeutic exercise method, and treadmill-walking rehabilitation, as investigated by Luft et al. (2008b), were identified as effective approaches. Dual-task walking exercises, involving performing tasks while walking, were considered as potential progressions in rehabilitation, although challenges may arise for patients with spasticity or paralysis.

Critically, the lack of follow-up in certain studies raises concerns about the sustainability of improvements over time. The 6-month follow-up in Peurala et al.'s study (2005b) serves as a model for assessing the enduring effects of therapeutic interventions on motor abilities, gait speed, dynamic balance, and motor tasks.

Proposing avenues for future research, combining therapeutic exercise methods from distinct studies may yield synergistic effects. For instance, integrating pelvic compression belts into resistance training methods or exploring the combination of ankle muscle strengthening with walking programs could enhance therapeutic outcomes.

In conclusion, the choice of a therapeutic exercise method for chronic stroke patients transcends mere study results. Clinical experience and patient preferences are pivotal factors, prompting a call for personalized therapy plans that align with individual patient goals. This narrative literature review provides a comprehensive exploration of various therapeutic exercise methods, laying the groundwork for further research and nuanced clinical decision-making in stroke rehabilitation.

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