THIS SYSTEMATIC REVIEW AIMS TO EVALUATE AND COMPARE THE EFFECTS OF TASK-SPECIFIC TRAINING AND CONVENTIONAL PHYSIOTHERAPY ON UPPER LIMB FUNCTION AMONG STROKE SURVIVORS.

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CERTIFICATION

This dissertation by **AGBONAVBARE DESTINY** is accepted in its present form as satisfying the dissertation requirement of the degree of Bachelor of Physiotherapy of the School of Basic Medical Sciences, College of Medical Sciences of the University of Benin.

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DEDICATION

To the Lord God Almighty, for His faithfulness, His boundless kindness and love towards me and for making me successfully complete my project work.

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ABSTRACT

Background: Stroke is a leading cause of long-term disability worldwide, often resulting in impaired upper limb function that limits independence in activities of daily living. Physiotherapy interventions play a crucial role in rehabilitation, with Task-Specific Training (TST) and Conventional Physiotherapy (CP) being commonly employed approaches. However, the comparative effectiveness of these interventions on upper limb recovery remains a subject of interest.

Objective: This systematic review aims to evaluate and compare the effects of Task-Specific Training and Conventional Physiotherapy on upper limb function among stroke survivors.

Methods: A systematic search of relevant electronic databases was conducted to identify studies comparing Task-Specific Training with Conventional Physiotherapy in stroke rehabilitation. Eligible studies included randomized controlled trials and experimental studies involving adult stroke survivors. Data regarding study characteristics, intervention protocols, outcome measures, and findings related to upper limb function were extracted and synthesized.

Results: The reviewed studies demonstrated that Task-Specific Training generally resulted in greater improvements in upper limb motor function, dexterity, coordination, and performance of daily activities compared to Conventional Physiotherapy. The repetitive practice of meaningful, goal-directed tasks promoted neuroplasticity and functional recovery. While Conventional Physiotherapy contributed to improvements in muscle strength, range of motion, and general mobility, its effects on functional upper limb use were often less pronounced than those observed with Task-Specific Training. Nevertheless, both interventions showed positive outcomes in stroke rehabilitation.

Conclusion: Evidence from the reviewed literature suggests that Task-Specific Training is more effective than Conventional Physiotherapy in enhancing upper limb function among stroke survivors. Incorporating task-oriented activities into rehabilitation programs may optimize functional recovery and improve patients' quality of life. Further high-quality studies are recommended to establish standardized treatment protocols and determine long-term outcomes.

CHAPTER ONE

INTRODUCTION

1.1 Background to the study

Stroke is defined as a rapidly developing focal or global sign of neurological disturbance attributed to vascular origin last for more than 24 hours or leading to death (Feigin *et al.*, 2025). Stroke is characterized by weakness of one side of the body, facial deviation, slurred speech and it is the leading cause of disability and death in the world (Wafa et al., 2020). One of the leading causes of neurological disability is stroke, with over 13 million of new cases annually in the world, and which usually leads to an intense functional impairment (Scorrano et al., 2018; Lindsay et al., 2019).

The Global Burden of Disease (GBD) 2021 study revealed that the global disability-adjusted life years (DALYs) attributed to stroke rose from 144.0 million in 2010 to 160.4 million in 2021 (Ferreira *et al.*, 2024). Additionally, it is estimated that globally, there are about 4.5millions deaths of people with stroke and there are approximately 102.2millions of people living with stroke (Lahoud et al., 2015). In European union, evidence shows that there are approximately 9.53 million stroke survivors with projections indicating a significant increase to around 12.11 million by 2047 (Wafa *et al.*, 2020). In Africa, the occurrence of stroke is 316 per 100,000 individuals annually, while 26 per 100,000 in Nigeria annually (Adeloye et al., 2019; Akinyemi et al., 2021).

Despite the increasing global prevalence of stroke, physiotherapeutic interventions have been associated with reduced mortality and improved recovery rates among stroke patients (Scorrano et al., 2018). A key objective of physiotherapy in stroke rehabilitation is to help patients achieve optimal levels of independence by the time of discharge (Ogwumike et al., 2014; Scorrano et al., 2018). However, Scorrano et al. (2017) noted that this level of independence is often not reached due to shortened hospital stays. However, continuous physiotherapy interventions which included evidence-based rehabilitation program has been shown to be effective in improving level of independence among stroke survivors.

Majority of individuals recovering from stroke experience persistent challenges in using their paretic hand during daily activities (Buma et al., 2013). Studies have shown that many stroke survivors identify improved upper limb (UL) function as one of their highest rehabilitation priorities (Kwakkel et al., 2003; Barker et al., 2007; Buma et al., 2013). Despite considerable investments in stroke rehabilitation, these individuals often encounter ongoing barriers to performing tasks independently at home. Research indicates that post-stroke survivors ultimately discontinue up to 57% of their daily activities, highlighting the profound impact of UL impairments on day-to-day functioning (Hartman-Maeir et al., 2007). Given the integral role both upper limbs play in the execution of routine tasks such as dressing, grooming, cooking, and writing, this decline in functional engagement is strongly influenced by upper limb paresis (Waddell et al., 2017). The inability to reintegrate the affected limb into meaningful activity not only impedes recovery but also negatively affects quality of life, independence, and psychosocial well-being (Rozevink et al., 2023). As such, targeted and intensive rehabilitation strategies aimed at enhancing UL function are critical to improving overall participation and reducing long-term disability among stroke survivors. Additionally, it is important to note that studies have shown that improvement in motor recovery in the UL does not translate to function in some cases (Higgins et al., 2005), hence the need for task specific training to improve UL functions.

Task-specific training refers to rehabilitation that centers on practicing everyday tasks the patient personally finds meaningful and wants to regain. Hubbard et al. (2009) define it as "training or intervention that employs ordinary, day-to-day activities that are intrinsically or extrinsically significant to the patient or client." Engaging stroke survivors in upper-limb rehabilitation grounded in this approach can restore a measurable portion of arm function (French et al., 2010). Research consistently shows that programs built around high-repetition, goal-directed practice of real-world actions achieve the best results. In contrast to impairment-based therapy whose primary aim is to reduce deficits such as weakness or restricted range of motion task-specific training focuses on relearning complete, purposeful activities (e.g., reaching for a cup or buttoning a shirt) (Hubbard et al., 2009; French et al., 2010). By aligning exercises with tasks, the individual values, therapists can enhance motivation, drive neuroplasticity, and ultimately improve both functional independence and quality of life after stroke (Valkenborghs et al., 2019).

Several studies have compared task-specific or functional training to other rehabilitation interventions, yielding mixed but insightful findings. For instance, a randomized controlled trial (RCT) by Thant et al. (2019) demonstrated that although task-oriented training significantly improved motor capacity in an intensive outpatient upper limb (UL) rehabilitation setting, these gains did not consistently transfer to increased UL performance in real-world environments outside the clinic. In contrast, RCTs conducted by Narayan et al. (2012) and Manzoor et al. (2023) found that task-specific training led to statistically significant and clinically meaningful improvements in upper extremity motor and fucntion recovery among individuals with subacute stroke. These studies emphasize the potential of task-specific interventions to promote neuroplasticity and functional restoration during critical windows of recovery. The variation in outcomes may be influenced by differences in intervention intensity, patient engagement, the timing of rehabilitation post-stroke, and environmental reinforcement of learned skills (Rozevink et al., 2023).

1.2 Statement of the Problem

Upper limb function is essential for performing everyday activities such as eating, dressing, writing, and grooming. After a stroke, many individuals experience upper limb weakness or paralysis, making it difficult to carry out these basic tasks and reducing their overall independence and quality of life (French et al., 2010). Although physiotherapy is central to stroke rehabilitation, many stroke survivors continue to have poor upper limb outcomes despite treatment. Task-specific training, which involves repetitive practice of meaningful daily activities, has been proposed as a more effective approach compared to conventional physiotherapy (Valkenborghs et al., 2019; Rozevink et al., 2023). However, existing studies have shown mixed results, and it remains unclear which approach yields better outcomes for upper limb recovery. Therefore, a systematic review is needed to compare the effects of task-specific training versus conventional physiotherapy on upper limb function in stroke survivors, to help guide clinical decision-making and improve rehabilitation outcomes.

1.1 Research questions

i. What are the commonly used task-specific training activities for the upper limb function in stroke survivors?

ii. What is the pooled effect of task-specific training on upper limb function in stroke survivors?

iii. How does task-specific training compare to conventional physiotherapy in improving upper limb function among stroke survivors?

1.2 Aim of study

i. To synthesize evidence on the effectiveness of task-specific training on upper limb function in stroke survivors.

1.3 Significance of study

i. **To Clinicians:** This study provides evidence-based insights into the comparative effectiveness of task-specific training versus conventional physiotherapy for upper limb rehabilitation in stroke survivors. By identifying which approach yields better functional outcomes, it will guide physiotherapists and rehabilitation specialists in selecting the most effective treatment strategies, improving patient recovery and clinical outcomes.

ii. **To the General Public and Stroke Survivors:** For stroke survivors and their families, the findings of this review can enhance understanding of available rehabilitation options. It empowers patients to make informed decisions, promotes engagement in meaningful recovery strategies, and supports a better quality of life through improved upper limb function.

iii. **To Policymakers and Health Administrators:** The study provides data that can inform rehabilitation guidelines, funding decisions, and the development of national stroke recovery programs.

iv. **To the Academic Literature:** This systematic review addresses a gap in the existing literature by synthesizing and comparing current evidence on task-specific training versus conventional physiotherapy. It contributes to the growing body of knowledge on stroke rehabilitation and identifies areas for further research, such as intervention timing, dosage, and long-term functional outcomes.

1.4 Delimitations

i. Only adult stroke survivors (≥18 years) will be included. Studies involving children, adolescents, or animal models are excluded.

ii. The review is limited to interventions clearly described as task-specific (or task-oriented) upper-limb training and to comparators defined as conventional physiotherapy delivered by rehabilitation professionals.

iii. Only randomised or quasi-randomised controlled trials will be reviewed. Observational studies, single-case designs, and qualitative reports are outside the scope.

iv. Articles must be published in English. Non-English papers will be excluded due to resource constraints for translation.

1.5 Definition of terms

i. Stroke: It can be defined as a clinical syndrome consisting of rapidly developing clinical signs of focal or global disturbance of cerebral function, lasting more than 24 hours or leading to death, with no apparent cause other than a vascular origin (WHO).

ii. Task specific training: Task-specific training refers to rehabilitation that centers on practicing everyday tasks the patient personally finds meaningful and wants to regain.

CHAPTER TWO

LITERATURE REVIEW

2.1 Preamble

This chapter discusses the definition of stroke, it's epidemiology, the global burden of stroke, classification of stroke, risk factors for stroke, clinical features of stroke, implication of stroke on motor function, pathology, and pathophysiology of stroke, impact of stroke on upper limb function, and role of task specific training and its effects on upper limb motor recovery, and a review of studies that involved the use of virtual reality game training in upper limb motor recovery in stroke survivors.

2.2 Definition of Stroke

Stroke has been widely discussed by scientists in history, although the terms used to describe it have varied over time. As such, they include apoplexy, cerebrovascular accident, amongst others (Engelhardt, 2017). According to the American Stroke Association (ASA), stroke is a disease that affects the arteries leading to and within the brain (Powers et al., 2019). The ASA further describes it as a "brain attack" that occurs when blood flow to a particular area of the brain is occluded (Sacco et al., 2013). A stroke can be defined as a neurological deficit that occurs as a result of an acute focal injury to the Central Nervous System (CNS) of vascular origin (Sacco et al., 2013). A stroke is not a blood clotting disorder within cerebral arterial vessels. Rather, it is a complex phenomenon created by the localization of thrombosis or hemorrhage within the intracranial vasculature due to varying degrees of vascular insufficiency and damage (Chang, 2020). The sequelae of symptoms associated with stroke depend on the location of the resultant infarct. With reference to clinical anatomy, the brain is supplied by the anterior, middle, and posterior cerebral arteries; all of which arise from the supraclinoid internal carotid arteries. Insufficiencies of any of these vessels may lead to damage ranging from mild to severe to the cerebral structures (Jauch et al., 2022).

2.3 Epidemiology of Stroke

According to World Health Organisation (WHO), the risk of developing a stroke has increased by 50% over the past 17 years with a 70% increase in stroke incidence and a 102% increase in stroke prevalence between 1990 to 2019 worldwide (Feigin et al., 2020). From World Stroke Organisation (WSO) statistics, there were 12,224,551 incident cases of stroke globally in 2022 with 6,437,105 female cases and 5,787,446 male cases. Also, the prevalent cases of stroke were 101,474,558 in total; with 45,036,191 male cases and 56,438,366 female cases accordingly (Feigin et al., 2022). Although extensive data on stroke surveillance in Africa may be lacking, current data shows that age-related mortality, case fatality, incidence, prevalence, and disability of stroke in Africa are similar to or higher than those of high-income regions (Sarfo et al., 2018). From a 2019 study, the rounded-up incidence of stroke in Nigeria was 26.0 (12.839.0) /100,000 person-years, with higher values among males at 34.1 (9.7-58.4) /100,000, compared to females at 21.2 (7.4-35.0) /100,000. The rounded-up prevalence of stroke survivors in Nigeria was 6.7 (5.8-7.7) /1000 population, also higher among the male population at 6.4 (5.1-7.6) /1000, compared to females at 4.4 (3.4-5.5) /1000 (Adeloye et al., 2019).

In addition to this, the case fatality rate of stroke in Africa is 35% on average but can range from 14.9% to as high as 77% when associated with cerebral hemorrhages. In contrast, the 30-day case fatality rate in Nigeria is 40% on average; generally ranging from 21% to 45% (Wahab et al., 2008).

2.4 Global Burden of Stroke

Stroke is a major health burden across the globe. In this regard, worldwide it is the second-leading cause of death, and the third-leading cause of death and disability combined (Jaberinezhad et al., 2022). Between the years 1990 and 2019, there has been a 43% increase in deaths due to stroke and a 143% increase in Disability Adjusted Life Years (DALY) globally. (Zhang et al., 2022). Strikingly, the lower and middle-income countries bear the bulk of the global stroke burden with 86% of deaths due to stroke and 89% of DALYs from the total global burden (Gall et al., 2022). Globally, 6,552,724 deaths per year are attributed to stroke with 51% (3,331,206) of deaths in males and 49% (3,221,518) of deaths in females (Feigin et al., 2022). Over 143 million years of healthy life are lost each year due to stroke related death and disability. Men account for 54% of healthy life lost due to stroke-related disability while women account for 46% of healthy life lost due to stroke-related disability (Feigin et al., 2022). In Nigeria, stroke accounts for 0.9%-4% of all hospital admissions and 2.8%-4.5% of total deaths (Oni et al., 2009). Also, more than 6.5 million deaths and 113.2 million disability-adjusted life years (DALY) have been attributed to stroke in Nigeria (Wahab et al., 2008).

2.5 Risk Factors for Stroke

Traditional risk factors for stroke are divided into modifiable and non-modifiable risk factors (Boehme et al., 2018). Common modifiable risk factors include hypertension, diabetes mellitus, high blood cholesterol, cardiovascular diseases, sedentary lifestyle, atrial fibrillation, smoking, and alcohol consumption (Oyinloye et al., 2020). While the non-modifiable risk factors include age and gender (Boehme et al., 2018).

Age is a major determining factor for stroke and a person's risk for stroke doubles every decade after the age of 55 (Donkor et al., 2018). In Sub-Saharan African countries like Nigeria, most stroke cases occur in people below the age of 60 years (Donkor et al., 2018). While in developed climes stroke affects older people between the ages of 70 and 75 years (Owolabi et al., 2018).

Following age, hypertension is the second major risk factor for stroke (Oni et al., 2008). People with hypertension are 3 to 4 times more likely to experience a stroke episode (Udoh et al., 2019). This higher tendency can be attributed to the composite adverse effects of hypertension on cerebral circulation (Donkor et al., 2018). In addition to this, sickle cell disease which is relatively widespread in Nigeria amongst other Sub-Saharan African countries increases the risk of stroke by 200-400 fold (Donkor et al., 2018; Oni and Olisah 2009). Previous history of a stroke episode also increases the risk of recurrence by 5-25% in 1 year and 20-40% in 5 years (Donkor et al., 2018).

In a study comparing the risk factors among stroke survivors in Nigeria and Germany, it was observed that hypertension was more common among Nigerian stroke survivors compared to smoking, hyperlipidemia, atrial fibrillation, congestive cardiac failure, ischemic heart disease, and atherosclerosis of the carotid and vertebral arteries; which were significantly more common among the German stroke survivors (Donnel et al., 2018; Oni and Olisah 2009). Also, while ischemic stroke is largely associated with smoking, hyperlipidemia, cardiac disease, and atherosclerosis, hypertension is more commonly associated with hemorrhagic stroke (Donkor et al., 2018).

Other risk factors for stroke include race, genetics, physical inactivity, stress oral contraceptive use, vasculitis, inflammatory processes, migraine, sleep apnea syndrome, prothrombin activator inhibitor complex deficiency, hypotension, high c-reactive protein, neurocysticercosis, Chlamydia pneumoniae, Helicobacter pylori, Legionella pneumophilia, chronic bronchitis, periodontal disease, and hyperuricemia (Chen et al., 2021; Olaleye et al., 2022; Oyediran et al., 2021). Common predictors of mortality following a stroke include older age, sex, and post stroke complications. Ages above 60 years are at higher risk of mortality, alongside post stroke complications (accounting for 23–50% of total deaths in patients with ischemic stroke. Albeit, the effect of a patient's sex as a predictor of mortality is still being debated (Ekeh et al., 2015).

2.6 Classification of Stroke

Stroke has been classified into two broad types which include hemorrhagic stroke, and ischemic stroke (Donnel et al., 2018). Hemorrhagic stroke has been further divided into two sub-types, which include subarachnoid hemorrhage (SAH), and intracerebral hemorrhage (ICH) (Zhang et al., 2018). According to the Trial of Org 10172 Acute Stroke Treatment (TOAST) classification, there are five subtypes of ischemic stroke which include large-artery atherosclerosis, cardioembolism, small-vessel occlusion (lacunar Infarcts), strokes of other determined etiology, and strokes of undetermined etiology (Simonsen et al., 2022).

Hemorrhagic strokes account for about 4.6 million new cases of stroke recorded globally each year, amongst which over 3.4 million cases are intracerebral hemorrhages.

Over 28% of all incident strokes globally are ICH strokes (Feigin et al., 2022). Furthermore, there are about 1.2 million new cases of SAH strokes globally each year and almost 8.4 million people currently live who have experienced SAH strokes (Feigin et al., 2022). Generally, there are over 7.6 million new ischemic strokes each year, and over 62% of all incident strokes across the globe are ischemic strokes (Feigin et al., 2022).

Recent data from an INTERSTROKE study, an international multicenter casecontrol study for stroke, has shown that the proportions of ischemic and hemorrhagic stroke in Africa are about 66% and 34%, respectively (Donkor et al., 2018). This is widely different from the situation in high-income countries with about 91% of ischemic strokes and 9% of hemorrhagic strokes (Donnel et al., 2018). Furthermore, data from the Stroke Investigative Research and Educational Network (SIREN) study in Nigeria has reported that 68% of strokes in Nigeria are ischemic, while 32% of strokes are hemorrhagic (Owolabi et al., 2018).

2.7 Clinical Features of Stroke

There is a large degree of specialization in the brain.

Neurological functions of the brain are divided between the two hemispheres of the brain and the brainstem. The clinical sequelae of stroke depend on the arterial territory of the circle of Willis associated with specialized centers damaged as a result of the interruption in blood flow (Teasell et al., 2021). This is accompanied by subsequent loss of the neurological functions controlled by the area of the stroke lesion (Ganesh et al., 2021; Teasell et al., 2020).

Strokes exhibit a wide diversity of clinical signs and symptoms. Contralateral hemiparesis or hemiplegia is the most common manifestation of stroke. Other neurological manifestations vary based on the side of the stroke lesion and based on whether the stroke occurs in the cerebral hemispheres or the brainstem (Ganesh et al., 2021).

Brain lesions associated with stroke include:

i. Hemispheric lesions

The brain hemispheres are supplied by the anterior carotid arteries. A disruption in blood flow within this arterial circulation of the brain will lead to left or right sided hemispheric lesions of the cerebral cortices. Hemispheric lesions often result in paralysis or weakness in the contralateral extremity, with associated sensory loss and homonymous hemianopsia (Ganesh et al., 2021). However, each hemisphere has a degree of specialization unique to it. Despite this, normal bodily functions require the integration of both hemispheric functions. (Teasell et al., 2020).

The MCA covers two-thirds of the lateral surface of the cerebral hemispheres. Involvement of the middle cerebral artery (MCA) of the circle of Wllis' in a stroke is more common when compared to anterior cerebral artery (ACA) involvement. Some clinical features of MCA infarcts include contralateral weakness/sensory loss, affecting the distal contralateral leg more than the upper extremity, mutism, urinary incontinence, contralateral grasp reflex and paratonic rigidity, transcortical motor aphasia (on left), gait apraxia (Teasell et al., 2020).

The ACA supplies the anterior and upper part of the cerebral cortex (Ganesh et al.,

2021). Infarctions involving the anterior cerebral artery account for 3% of all strokes. Some clinical features of ACA infarcts include contralateral hemiparesis/hemiplegia, contralateral sensory loss, contralateral homonymous hemianopsia, left hemispheric aphasia, right hemispheric visual perceptual deficits including left hemineglect (Rozema et al., 2020; Adeoye et al., 2021).

Hemispheric lesions can be divided into:

a. Right Hemisphere Disorders: The right hemisphere mediates learned behaviors that require voluntary initiation, planning, and spatial perceptual judgment (Teasell et al., 2020).

Clinical signs and symptoms majorly associated with the right hemisphere include visual-spatial perceptual deficits, anosognosia, emotional disorders, and subtle communication problems (Zhang et al., 2021).

b. Left Hemisphere Disorders: The Left hemisphere is associated with learning and language use. Clinical signs and symptoms majorly associated with the left hemisphere include aphasia (paraphasia, broca's aphasia, anomic aphasia, transcortical motor aphasia, Wernicke's aphasia, transcortical sensory aphasia, conduction aphasia, and global aphasia), apraxia (motor or ideomotor,

constructional apraxia, apraxia of speech, dressing apraxia, and apraxia of gait), and emotional disorders (Schuster et al., 2022; Terasawa et al., 2021).

ii. Pontine infarcts

The Pontine region of the brain is supplied by the pontine arteries that arise from the Basilar Artery (Ganesh et al., 2021). Clinical signs and syndromes associated with pontine lesions include spastic hemiplegia contralaterally, hemisensory loss contralaterally, ipsilateral Ataxia, ipsilateral Facial weakness, ipsilateral Facial sensory loss, ipsilateral Hearing loss, vertigo, lateral gaze palsy, and dysphagia (Smith et al., 2021; Moon et al., 2020).

iii. Lateral medullary syndrome (Wallenberg's syndrome)

Lateral Medullary Syndrome is associated with occlusion of vertebral arteries or posterior inferior cerebellar artery (PICA) (Ganesh et al., 2021). Clinical signs and symptoms associated with lateral medullary syndrome include Horner's syndrome (ptosis, anhydrosis, and miosis) Ipsilaterally, ipsilateral decrease in pain and temperature sensation of the face, cerebellar signs such as ataxia, decreased pain and temperature contralaterally, dysphagia, dysarthria, hoarseness, and paralysis of the vocal cord, vertigo, nausea, vomiting, hiccups, nystagmus, and diplopia (Teasell et al., 2020).

iv. Medial medullary syndrome

Medial Medullary Syndrome is associated with occlusion of the penetrating paramedical branches of the anterior spinal, vertebral or basillar arteries (Siddik et al., 2023; Kim, 2016). Clinical signs and symptoms associated with medial medullary syndrome include ipsilateral hypoglossal palsy, contralateral hemiparesis, and lemniscal sensory loss (i.e proprioception and position sense).

v. Cerebellar lesions

The Cerebellar region of the brain is supplied by the vertebral-basilar/ posterior and inferior circulation of cerebral arteries (PICA). Strokes that occur within this vascular distribution are associated with bilateral visual and cranial nerve problems, vertigo, dysarthria/dysphagia, diplopia, facial numbness or paresthesia, motor hemiparesis or quadriparesis, ataxia, hemi or bilateral sensory loss, drop attacks. However, clinical signs and symptoms associated with cerebellar lesions include ataxia, dyssynergia (impaired coordination of muscles involved in a single movement), dysmetria (impaired measure and extension as well as the speed of intended movement), intention tremor, dysdiadokinesis (abrupt and jerky movements on alternating movements of agonists and antagonists), nystagmus, and cerebellar (scanning and explosive) dysarthria (El Amki et al., 2021).

2.8 Pathology and Pathophysiology of Stroke

Strokes are caused by impaired circulation to organs of the brain (Li et al., 2017). Arterial supply to the brain is through the internal carotid arteries anteriorly and vertebral artery posteriorly

(Ganesh et al., 2021). Ischemic strokes occur when there is insufficient blood and oxygen supply to the brain while hemorrhagic stroke is caused by bleeding of blood vessels (Orellana-Urzúa et al., 2020).

Ischemic strokes can be divided into thrombotic and embolic ischemic strokes based on pathology (Abdulkarim et al., 2021). Thrombotic ischemic strokes are brought about by occlusion of blood flow by the narrowing of blood vessels from atherosclerotic plaque buildup which eventually leads to the blockage of these blood vessels (Huang et al., 2021). However, in the case of an embolic ischemic stroke, decreased blood flow is caused by a blood clot from other parts of the body being dislodged and occluding arterial circulation of narrow vessels, in turn leading to severe stress on brain tissue followed by tissue damage (Li et al., 2017).

When an ischemic stroke occurs, there are two areas of damage. These include the core and the penumbra (Orellana-Urzúa et al., 2020). At the core, a reduction in blood flow to cells usually leads to irreversible damage and cell death. However, in the penumbra region bordering the Infarct, the severity of damage is less (Orellana-Urzúa et al., 2020). Although cells in this area are at risk of complete cell death, the region is rendered inactive by reduced blood flow but still retains its metabolic functions. If blood flow and oxygen are eventually restored, this area resumes normal function (Xing et al., 2014). Otherwise, they may undergo apoptosis after hours or days following the damage (Broughton et al., 2009).

When the brain undergoes ischemic damage, the ischemic cascade commences after a short period of time (Li et al., 2017). The ischemic cascade is a series of biochemical reactions, the duration of which ranges from two to three hours to a few days. It may continue even after normal blood flow is restored (Orellana-Urzúa et al., 2020). An inadequate blood supply has adverse effects on the energy production of affected brain cells (Abdulkarim et al., 2021). These brain cells are unable to produce adenosine triphosphate (ATP). Therefore, they undergo anaerobic metabolism causing brain cells to release lactic acid as a by-product (Xing et al., 2014).

Lactic acid is an irritant with the potential to destroy cells by disrupting the normal pH of the brain. This causes failure of the ATP transport pumps causing depolarization of the cell membrane and leading to an influx of calcium ($Ca^{2}+$) ions and efflux of potassium ions. High calcium levels trigger the release of glutamate which is an excitatory amino acid neurotransmitter (Rehman et al., 2021).

On the other hand, hemorrhagic stroke is caused by rupturing of blood vessels. In this condition, internal injury amongst other factors may cause blood vessels to rupture (Chen et al., 2014). This causes hematoma formation. Hematoma compresses brain tissue and can cause distortion or injury to tissue (Chung et al., 2021). Furthermore, pressure may lead to a loss of blood supply to affected tissue with resulting infarction, and the blood released by brain hemorrhage appears to have direct toxic effects on brain tissue and vasculature (Khalil et al., 2016).

ICH is usually caused by an accumulation of blood within the brain from a ruptured blood vessel (Ní-Chróinín et al., 2021). This is usually a result of blood vessel damage from chronic hypertension, vascular malformations, or the use of medications associated with increased bleeding rates, such as anticoagulants, thrombolytics, and antiplatelet agents (Wang et al., 2017).

SAH is caused the gradual collection of blood in the subarachnoid space of the brain dura, typically caused by trauma to the head or the rupture of a cerebral aneurysm. It produces toxic effects on the vascular system, resulting in infarction (Chen et al., 2014).

2.9 Impact of Stroke on Upper Limb Motor Function

Strokes lead to impairments of upper limb structure and function (Raghavan, 2015). Weakness or paresis is the predominant impairment that contributes to dysfunction after stroke (Wagner et al., 2007). Also, unilateral stroke produces debilitating deficits in voluntary control in the contralesional arm, and significant motor coordination deficits in the ipsilesional arm (Sainburg et al., 2013). In addition, stroke may result in distorted tactile sensation, and proprioception, alongside deficits in higher-order sensory modalities such as deficits in 2-point discrimination, kinesthetic sense, and grasp which may be associated with the degree of weakness and stroke severity (Tyson et al., 2008).

Upper limb motor impairments during stroke are a direct consequence of the lack of signal transmission from the motor cortex which generates the impulse for all the facets of movement and transmits it to the spinal cord, which executes the movement via signals to muscles (Raghavan, 2015). This lack of transmission in turn causes delayed initiation and termination of muscle contraction, and slowness in developing force manifested as an inability to move or move quickly with negative functional consequences (Raghavan, 2015).

Hence, when the paretic limb is forced to move, weakness, sensory impairments, and pain can prevent normal movement. Compensatory strategies of movement are used instead to complete tasks (Levin et al., 2009). Furthermore, stiffness and contractures resulting from immobility, spasticity, and abnormal motor synergies can contribute to compensatory movements such as human reaching and grasping after a stroke (Raghavan, 2015). Patients with stroke commonly use trunk flexion rather than elbow extension to reach for objects. In addition, they use forearm pronation and wrist flexion rather than neutral forearm position and wrist extension to orient the hand for grasping. Also, the metacarpophalangeal joint is used for flexion rather than proximal interphalangeal joint flexion to grasp objects (Levin et al., 2009).

Another major implication of stroke on the affected upper limb is that non-use resulting from weakness/paresis or sensory loss may occur (Wagner et al., 2007). As time progresses, this may become habitual as stroke survivors may neglect the limb and in turn do not incorporate it into functional activities, even though they can move it. Non-use over time becomes a learned behavior and is referred to as learned nonuse (Wagner et al., 2007).

Furthermore, stroke survivors tend to easily forget new upper extremity motor skills learned if there is a break in rehabilitation post-stroke. This is because learning new motor skills post stroke is associated with three processes occurring across multiple timeframes. They include adaptation which is a fast learning process that is easily forgotten, repetition which leads to tuning out of directional biases and lastly, reinforcement. It has been shown that learning is more successful when sensorimotor adaptation is combined with the repetition of movements.

2.10 Impact of Stroke on Upper Limb Activities of Daily Living

The implications of stroke on upper limb motor function are vast and can have significant negative impacts on activities of daily living, and independence of affected individuals. An increased severity of motor dysfunction is associated with decreased affected upper limb activity and dependence in Activities of Daily Living (ADL) (Sainburg et al., 2013).

The Implication of upper limb motor dysfunction on activities of daily living is significant. It can hinder self-care activities such as bathing, dressing, feeding, and grooming (Yadav et al., 2014). Moreover, it can affect activities that require fine motor control, such as writing, typing, and cooking . This can significantly reduce an individual’s independence and their ability to engage in meaningful social activities, which can lead to depression and social isolation (Yadav et al., 2014). Also, stroke survivors tend to avoid bilateral arm patterns during the performance of activities of daily living (Sainburg et al., 2013). Effective rehabilitation interventions can improve upper limb motor function and enhance the quality of life of stroke survivors (Mukherjee et al., 2020).

2.11 Diagnosis of Stroke

The diagnosis of stroke involves the processes mentioned below:

i. History taking and assessment

History taking and assessment are the first point of call in the diagnosis of stroke. In a study that involved primary care physicians, a 92% sensitivity of primary care physicians diagnosing strokes based on assessment and history taking alone was recorded (Musuka et al., 2014). Stroke can be categorized as ischemic stroke and hemorrhagic stroke (Teasell et al., 2020). The hallmark for diagnosis of ischemic stroke is awakening with or experiencing the abrupt onset of focal neurologic deficits (Weisenburger-Lile, et al., 2022). Common presenting symptoms of ischemic stroke include speech disturbance and weakness in onehalf of the body (Teasell et al., 2020). It is also necessary to take note of the time of onset of symptoms. This determines whether a patient meets the 3-4.5-hour eligibility windows for thrombolysis among persons with a diagnosis of ischemic stroke (Yew et al., 2014).

ii. Diagnostic imaging

In the diagnosis of stroke neuroimaging is required to differentiate ischemic stroke from an intracerebral hemorrhage, as well as to diagnose entities other than stroke (Unnithan et al., 2022). The choice of neuroimaging depends on the availability of the method, the patient's eligibility for thrombolysis, and the presence of contraindications (Ziu et al., 2022). It is recommended that all patients with stroke symptoms should undergo urgent neuroimaging with Computed Tomography (CT) or Magnetic Resonance Imaging (MRI). CT is the imaging test of choice for SAH (Unnithan et al., 2022). Funduscopy is also recommended if intraocular hemorrhages are suspected (Ziu et al., 2022).

2.12 Management of Stroke

This section discusses the pharmacological management of stroke, the surgical management of stroke, and the non-pharmacological management of stroke.

2.12.1 Non-pharmacological management of stroke

This section discusses the non-pharmacological management of stroke which include, and Physiotherapy approaches to the non-pharmacological management of stroke.

2.12.2 Conventional physiotherapy treatment

2.12.3 Task Specific training and its impact on upper limb functions on stroke survivors

Stroke is a leading cause of long-term disability globally, with upper limb impairment affecting approximately 69% of survivors, 32% of whom experience severe paresis. This significantly impacts quality of life and daily activities. Task-specific training, a rehabilitation approach emphasizing functional, everyday task practice, has emerged as a promising strategy to address these challenges. Task-specific training is rooted in motor learning and neuroplasticity principles, contrasting with traditional impairment-based therapies that focus on isolated movements. It involves repetitive, high-intensity practice of meaningful tasks, such as reaching or grasping, tailored to the individual's needs. These tasks can be unilateral or bilateral and may incorporate assistive devices like robotic systems or virtual reality to enhance precision and engagement. The approach aims to promote neural reorganization, improving motor function and functional mobility.

A systematic review and meta-analysis published in Rozevink et al. (2021), compared task-specific training with assistive devices (TST-AAD) to task-specific usual care (TSUC). It included 17 studies with 383 participants, finding both approaches improved upper limb performance. TST-AAD was more effective in the subacute phase (early after stroke), with training durations ranging from 6 to 32 hours, based on Fugl-Meyer Assessment (FMA-UE) scores. In the chronic phase (later after stroke), both methods were equally effective, suggesting assistive devices provide added benefits during early recovery.

Another meta-analysis by jin et al. (2025) focused on robot-assisted task-oriented training, including 15 studies with 574 participants. It reported significant improvements in upper limb motor function, with FMA-UE showing a standardized mean difference (SMD) of 1.01 (95% CI: 0.57, 1.45) and Modified Barthel Index (MBI) an SMD of 0.61 (95% CI: 0.41, 0.82). High heterogeneity was noted, but subgroup analyses by combined interventions, age, and regions confirmed robustness, with publication bias tests (Egger's p=0.93) showing no significant bias.However, the ICARE trial, published in Wincester et al. (2016), presented mixed results. This phase 3, pragmatic, single-blind randomized trial involved 361 participants with moderate motor impairment, comparing a structured task-oriented program (ASAP) with usual and customary occupational therapy (UCC) over 44 months. With 304 (84%) completing 12-month assessments, it found no significant improvement in motor function with ASAP compared to UCC, based on the Wolf Motor Function Test (WMFT) time score changes (no significant between-group differences). This suggests implementation, dosage (30 one-hour sessions over 10 weeks), and timing may influence outcomes.

Table 1: Summary of Studies on Task-Oriented and Robot-Assisted Training for Upper Limb Function After Stroke

Source	**Title**	**Aim**	**Study Characteristics**	**Results**	**Conclusion**
Rozevinik et al. (2021).	Effectiveness of task-specific training using assistive devices and task-specific usual care on upper limb performance after stroke: a systematic review and meta-analysis	To investigate whether task-specific training using assistive arm devices (TST-AAD) improved upper limb performance compared to task-specific usual care (TSUC), and to assess retention of training	Systematic review and meta-analysis of 17 studies with 383 participants. Compared TST-AAD with TSUC in sub-acute and chronic phases. Training ranged from 6 to 32 hours.	Both improved performances. TST-AAD more effective in sub-acute phase; similar effects in chronic phase. No significant differences at follow-up.	TST-AAD improves performance, especially in sub-acute phase. Useful for home use; more research on cost-efficiency needed.

		effects.			
Jin et al. (2025)	Effectiveness of robot-assisted task-oriented training intervention for upper limb and daily living skills in stroke patients: A meta-analysis	To determine the intervention effects of robot-assisted task-oriented training on enhancing upper limb function and daily living skills in stroke patients.	Meta-analysis of 15 RCTs with 574 participants. Compared robot-assisted training with conventional therapies.	Significant improvement in motor function (SMD = 1.01) and daily living skills (SMD = 0.61). High heterogeneity for motor function, not for daily living skills.	Robot-assisted training significantly enhances upper limb function and daily living skills.
Wang et al. (2024)	Efficacy of Robot-assisted Training on Upper Limb Motor Function After Stroke: A Systematic Review and Network Meta-analysis	To systematically evaluate efficacy of robot-assisted training (RAT) on upper limb motor function and compare different RAT types.	Network meta-analysis of 31 RCTs with 1537 participants. Compared RAT+CRT vs CRT. Analyzed end-effector vs exoskeleton RAT.	RAT+CRT improved motor function and daily activities. End-effector best for motor function, exoskeleton best for daily activities.	RAT with CRT improves function and daily activities. End-effector best for motor, exoskeleton for daily skills.

Winstein et al. (2016)	Effect of a Task-Oriented Rehabilitation Program on Upper Extremity Recovery Following Motor Stroke: The ICARE Randomized Clinical Trial	To test efficacy of structured task-oriented upper extremity training (ASAP) vs usual care (UCC) in stroke patients.	Phase 3 RCT with 361 participants in 7 hospitals. Compared ASAP, DEUCC (dose-equivalent), and UCC. Outcome: WMFT at 12 months.	No significant differences in WMFT scores between groups. All showed similar improvements.	Structured task-oriented training was not superior to usual care.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Review

This review will be carried out following the guidelines of Cochrane Handbook for Systematic Reviews of Interventions and in accordance with the Preferred Reporting Items for Systematic review and Meta-analysis (PRISMA) guidelines (Page et al., 2021). A review protocol will be developed and registered with the Prospective Register of Systematic Review (PROSPERO) database.

3.2 Study Criteria and Selection

3.2.1 Framework

In this systematic review, the PICOT framework will be used to structure the inclusion and exclusion criteria for study selection ensuring that the review process is guided by the research questions.

3.2.2 Inclusion criteria

Population: Stroke survivors with upper limb motor impairment

Intervention: Task-specific training (TST) interventions targeting upper limb function (e.g., reaching, grasping, lifting tasks in real-life contexts)

Comparison: Conventional physiotherapy (standard neuro-rehabilitation techniques, including passive range of motion, strength training, or general exercises)

Outcome: Improvement in upper limb function (e.g., assessed using Fugl-Meyer Assessment, Wolf Motor Function Test, Action Research Arm Test, etc.)

Type of Study: randomized and non-randomized controlled trials (RCTs)

3.2.3 Exclusion Criteria

Studies will be excluded if they involve participants not diagnosed with stroke, such as those with traumatic brain injury or other neurological conditions. Additionally, studies that focus on lower limb rehabilitation or general motor function without specific outcome measures related to upper limb function will be excluded. Non-English language publications and non-peer-reviewed literature, including conference abstracts, dissertations, editorials, and opinion pieces, will also be excluded from the review.

3.3 Search Strategy

The following electronic databases will be used for the search: Goggle Scholar, PEDRO, CINAHL, Cochrane library and PUBMED. The search will include a combination of Medical Subject Headings (MeSH) and free-text terms related to the population, intervention, comparison, and outcome of interest. Keywords will include: "stroke", "cerebrovascular accident", "CVA", "upper limb", "upper extremity", "arm function", "task-specific training", "task-oriented", "task-based", "conventional physiotherapy", "traditional physiotherapy", "standard therapy". Boolean operators such as AND and OR will be used to combine terms appropriately. The search will be limited to peer-reviewed studies published in English. The reference list of all the included studies will be hand searched for additional eligible studies.

3.4 Study Selection

All the articles found from the databases will be exported into the COVIDENCE, a systematic review software where duplicates will be removed. Two reviewers will independently screen the titles and abstracts of all identified studies to assess their eligibility based on the inclusion criteria. Full-text articles screening will be conducted independently by both reviewers. Any disagreements arising during the screening process will be resolved through discussion and consensus. If a consensus cannot be reached, a third reviewer will be consulted to make the final decision.

3.5 Data Extraction

Data extraction will be carried out independently by two reviewers using a standardized form designed to capture key information from each study. Extracted data will include the study title, author(s), year of publication, country, study design, sample size, participant characteristics (such as age, gender, and stroke details), details of the intervention (type, duration, frequency of task-specific training), comparison treatment (conventional physiotherapy protocol), outcome measures related to upper limb function (e.g., Fugl-Meyer Assessment, Action Research Arm Test), main findings, statistical significance, and duration of follow-up if applicable. Any discrepancies between reviewers will be resolved through discussion or consultation with a third reviewer to ensure accuracy and consistency.

3.6 Quality Appraisal

The methodological quality and risk of bias of the included studies will be assessed independently by two reviewers using the Physiotherapy Evidence Database (PEDro) Scale for randomized controlled trials. The PEDro scale assesses internal validity and statistical reporting based on 11 items, including random allocation, concealed allocation, baseline comparability, blinding, adequate follow-up, intention-to-treat analysis, and between-group statistical comparisons. Each study will receive a total PEDro score out of 10 (item 1 is not included in the final score). Studies will be rated as: High quality: 7–10, Moderate quality: 4–6 and Low quality: ≤3. Disagreements in scoring will be discussed and resolved by consensus or adjudicated by a third reviewer.

3.7 Data synthesis

Data from the included studies will be synthesized both narratively and, where appropriate, quantitatively. A narrative synthesis will describe and compare the study characteristics, interventions, and outcomes across studies, highlighting patterns, similarities, and differences.

3.8 Data analysis

A combination of Qualitative Synthesis and Quantitative Synthesis (Meta-Analysis), was used to analyze the extracted data. The qualitative synthesis involved a comprehensive examination and interpretation of the qualitative findings from the included studies, allowing for the identification of common themes, patterns, and trends related to task specific training. For the quantitative synthesis, a Meta-Analysis (MA) was conducted using Review Manager Version 5.3.82. This involved a statistical pooling of relevant quantitative data from the selected studies to derive summary effect sizes and measures of precision. The level of significance was set at 0.05, ensuring a standard threshold for statistical significance.

3.9 Ethical Approval

Ethical approval would be sought and obtained from the Research and Ethics Committee of the College of Basic Medical Sciences, University of Benin.

CHAPTER FOUR

RESULTS

4.1 Results of Literature Search

A total of 710 studies were identified through the search strategies. After title and abstract screening, 654 studies were excluded, leaving 56 for full-text review. Following application of the inclusion criteria, 23 studies were deemed suitable for this review, as illustrated in Figure 1.

4.2 Summary of Methodological Quality of Included Studies

All of the included studies reported randomization of participants (100%). A majority described the use of a clear randomization sequence or allocation concealment (approximately 87%). However, only a smaller proportion of studies explicitly reported double-blinding procedures (around 65%), which is often challenging in rehabilitation trials. Most of the included studies demonstrated high methodological quality (about 82%), but a substantial number enrolled fewer than 50 participants (around 48%). Based on study quality and sample size, 80% of the included studies provided Level-1 evidence, while 20% provided Level-2 evidence, as summarized in Table 4.1.

The interventions assessed across trials were diverse and included: task-oriented training (TOT) (100%), functional electrical stimulation (FES) (100%), Brunnstrom Movement Therapy (BMT) (100%), progressive abduction loading therapy (100%), robot-assisted rehabilitation (100%), electroencephalography (EEG)-based motor imagery brain-computer interface (BCI) (100%), orthosis-assisted training (100%), mental practice-based rehabilitation (MP) (100%), TENS-assisted task-related training (TRT+TENS) (100%), motion capture rehabilitation (100%), and meaningful task-specific training (MTST) (100%).

Overall, the methodological quality of the included studies was strong, with consistent use of randomized designs and appropriate outcome measures. However, limitations included variations in blinding, small sample sizes in some trials, and heterogeneity of interventions, which may affect generalizability of the findings.

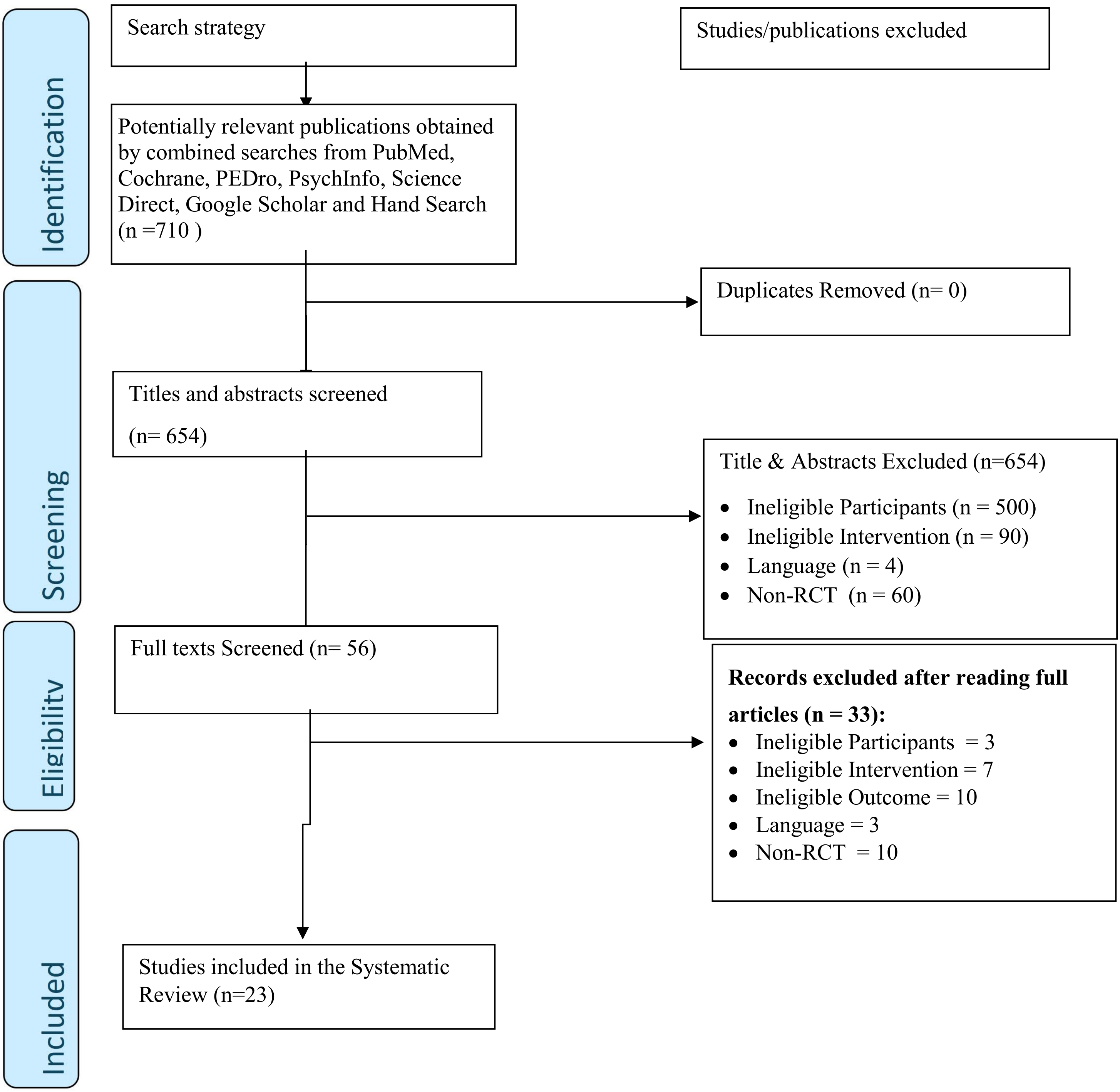

Figure 4.1: PRISMA Diagram

Table 4.1: Summary of Methodological Quality of Studies (N = 23)

S/N	Study	Country	Study design	Sample size	Comparison	Outcome/measure	Result	Conclusion
1	Jonsdottir et al., 2017	Italy	Randomized control trial	68	MeCFES assisted TOT	Upperlimb function	Sixty eight subjects completed the protocol (Mean age 66.2, range 36.5–88.7, onset months 12.7, range 0.8–19.1) of which 45 were seen at follow up 5 weeks later. There were significant improvements in both groups on ARAT (median improvement: MeCFES TOT group 3.0; C-TOT group 2.0) and FMA-UE (median improvement: M-TOT 4.5; C-TOT 3.5). Considering subacute subjects (time since stroke < 6 months), there was a trend for a larger proportion of improved patients in the M-TOT group following rehabilitation (57.9%) than in the C-TOT group (33.2%) (difference in proportion improved 24.7%; 95% CI -4.0; 48.6), though the study did not meet the planned sample size.	This is the first large multicentre RCT to compare MeCFES assisted TOT with conventional care TOT for the upper extremity. No adverse events or negative outcomes were encountered, thus we conclude that MeCFES can be a safe adjunct to rehabilitation that could promote recovery of upper limb function in persons after stroke, particularly when

								applied in the subacute phase.
2	da Silva et al., 2015	Brazil	RCT	20	TOT_ST rehabilitation protocol, Muscle strength training	Upper Extremity Performance Test, shoulder flexor and handgrip strength, shoulder active range of motion, motor impairment (Fugl-Meyer Scale), and muscle tone.	The TOT_ST group demonstrated better scores relating to unilateral tasks and in the quality aspects of bilateral movements (The Upper Extremity Performance Test, P = 0.04) at the end of rehabilitation protocol. The highest muscle force gain was reached by the TOT_ST group for the shoulder flexors (P = 0.001). Similarly, the active range of motion (P = 0.01) and Fugl-Meyer scores (P = 0.001) were higher in the TOT_ST group compared with the TOT group. Both groups showed improvement after training.	Strength training was able to intensify the upper-limb rehabilitation, as demonstrated by the superior scores achieved by the TOT_ST group in most of the evaluated parameters. Muscle strength training might be a pivotal element of the task-oriented rehabilitation program of chronic patients with mild impairment after stroke.
3	Kim, T. H., In, T. S., & Cho,	Korea.	RCT	30	TRT with TENS	Fugl-Meyer assessment scores (FMA), Manual function test (MFT), Box	Both groups showed significant improvements in FMA, MFT, and BBT after intervention. When compared with the TRT+PLBO group, the TRT+TENS group showed significantly greater improvements in FMA (p = 0.034), MFT (p = 0.037), and BBT (p = 0.042). In MAS score, significant	Our findings indicate that TRT with TENS can reduce motor impairment and improve motor activity in stroke survivors with chronic

	H. Y. (2013).					and block test (BBT), and Modified Ashworth scale (MAS	improvement was observed only in the TRT+TENS group (p = 0.011).	upper limb paresis, highlighting the benefits of somatosensory stimulation from TENS.
4	Ellis et al., 2018	USA	RCT	32	Progressive Abduction Loading Therapy with Horizontal-Plane Viscous Resistance	Flexion synergy, Muscle strength and reaching function	There was no difference between groups on any outcome measure. However, for combined groups, there was a significant increase in reaching distance (13.2%, effect size; d = 0.56) and velocity (13.6%, effect size; d = 0.27) at posttesting that persisted for 3 months and also a significant increase in abduction, elbow extension, and external rotation strength at posttesting that did not persist 3 months. Similarly, the clinical battery demonstrated a significant improvement in participant-reported measures of "physical problems" and "overall recovery" across all participants.	The JTHFT dexterity scores in the Upper The strengthening approach of incorporating horizontal-plane viscous resistance did not enhance the reaching function improvements observed in both groups. Data do not support the postulation that one can be trained to "overpower" the flexion synergy with resistance training targeting constitutive

								joint torques of reaching. Instead, flexion synergy must be targeted with progressive abduction loading to improve reaching function.
5	Cannell et al., 2018	Australia.	RCT	73	Motion capture rehabilitation	Functional reach, lateral reach, step test, sitting balance, arm function, and walking.	Participants (mean 22 days post-stroke) attended mean 14 sessions. Both groups improved (mean (95% confidence interval)) on primary outcome functional reach (usual care 3.3 (0.6 to 5.9), intervention 4.1 (−3.0 to 5.0) cm) with no difference between groups (P = 0.69) on this or any secondary measures. No differences between the rehabilitation units were seen except in lateral reach (less affected side) (P = 0.04). No adverse events were recorded during therapy.	Interactive, motion capture rehabilitation for inpatients post stroke produced functional improvements that were similar to those achieved by usual care stroke rehabilitation, safely delivered by either a physical therapist or a rehabilitation assistant.
6	Karakuş et al. (2013)	Turkey	RCT	28	Functional electrical	Upper limb motor function	Total upper extremity Motricity index scores were not different between the groups at the beginning (p=0.142). Intragroup analyses of the Motricity index showed that there	Adding functional electrical stimulation to standard rehabilitation program has a

					stimulation		was a statistically significant improvement in total Motricity index score in functional electrical stimulation group (n=14) (p=0.027), however, other studied parameters did not improve significantly (p>0.05). None of the studied parameters statistically significantly improved in the standard rehabilitation group (n=14) (p>0.05).	positive improving effect on the upper limb motor function in patients with post-stroke hemiplegia.
7	Chughtai et al. (2025)	Pakistan	RCT	16	Brunnstrom Movement Therapy	Upper limb function and grip strength	Both therapies significantly improved upper limb function and grip strength (p < 0.001). The BMT group exhibited a greater improvement in FMA-UE scores (45.8 ± 4.9 vs. 42.3 ± 5.0, p = 0.04) and grip strength (24.6 ± 3.5 kg vs. 22.1 ± 3.3 kg, p = 0.03) compared to the MT group. The percentage increase in FMA-UE was 29.01% for BMT and 17.50% for MT, while grip strength improved by 33.70% in the BMT group and 18.18% in the MT group.	Both interventions contributed to upper limb motor recovery, but Brunnstrom Movement Therapy demonstrated superior effectiveness in improving motor function and grip strength. These findings suggest that task-specific training may yield better functional outcomes in stroke rehabilitation.

8	Arya et al. 2012	India	RCT	103	Meaningful Task-Specific Training (MTST) program	Upper limb motor function .	The MTST produced statistically significant and clinically relevant improvements in the upper extremity motor recovery of the patients who had a subacute stroke compared to the control group	People 4 to 24 weeks after a first episode of unilateral stroke with Brunnstrom stage of arm recovery of 2 to 5.
9.	Caurau gh et al., (2011).	Florida	RCT	18	Rehabilitation over 16 months provided by various bilateral arm movements and coupled	Motor capabilities	Mixed design ANOVAs (Group × Retention Test: 2 × 4; Group × Retention Test × Arm Condition: 2 × 4 × 2) revealed improved motor capabilities for the long-term practice duration group on each primary measure. At the 16-month delayed retention test, when compared to the short-term group, the long-term group demonstrated: (a) more blocks moved (43 v 32), (b) faster premotor reaction times (158 v 208 ms), and (c) higher force production (75 v 45 N).	Sixty hours of rehabilitation over 16 months provided by various bilateral arm movements and coupled active stimulation improved motor capabilities in chronic stroke.

					active stimulation			
10.	Desta 2025	Italy	RCT.	40	Task-Oriented Training Group (TOTG)	ROM and nuscle strength	Task-oriented training significantly enhances functional recovery of the upper limb in post-stroke hemiparesis supporting its integration into standard neurorehabilitation protocols. TOT participants demonstrated statistically significant improvements in FMA-UE scores WMFT times and MAL scores compared to the control group.	This intervention is planned to continue as it produces increased satisfaction for the stroke survivor and carer, is an adjunct to existing services at OPH and is in line with recommendations from NSF.
11	Timmermans et al. 2013	The Netherlands	RCT	42	A 6-week additional mental practice (MP)-based	Upperlimb function	Training benefits depend on the initial level of functioning. Low-level subjects seemed to benefit most from TRT showing increased substitutive trunk use but also straighter hand paths suggesting better coordination.	High-level subjects whose kinematics showed fairly normal movement demonstrated less compensatory movement after PRE.

					rehabilitation			
12.	Hubbard et al. 2015	Australia	RCT	10	Task-specific UL training	Upper-limb motor function	Early more-intensive UL training was associated with greater changes in activation in putative motor (supplementary motor area and cerebellum) and attention (anterior cingulate) regions.	The intensive-training group also showed more consistent and predictable improvement in motor outcomes.
13.	Thielman, 2013	USA	RCT.	21	Extended task-related training (TRT)	Kinematic shoulder and elbow motion	Significant initial changes were maintained for kinematic shoulder and elbow motion, as well as functional measures. Compensatory reaching involving the trunk has been shown to be maintainable, but ultimately less efficient.	Training that involves a conscious decision to control the trunk led to the most improved functional performance, and may lead to ideal restorative strategies.
14	Lin et al., 2017	Taiwan	RCT	18	Orthosis	Range of motion of shoulder flexion and abduction	All five Fugl-Meyer assessment subscores improved in both the device and control groups after intervention; in particular, the "shoulder/elbow/forearm" subscore (P=0.02, 0.03) and "total score" (P=0.03, 0.03) substantially improved. The active range of motion of shoulder flexion and abduction	The designed wearable devices are practical and efficient for use in chronic patients with stroke.

							substantially improved at pre-post treatment in both the device (P=0.02, 0.03) and control (P=0.02, 0.03) groups. The deviation angle of shoulder external rotation during shoulder abduction substantially improved in the device group (P=0.02), but not in the control group.	
15.	Ang et al., 2014	Singapore	RCT	21	Electroencephalography (EEG)-based Motor Imagery (MI) Brain-Computer Interface (BCI)	Arm Function	In all, 14 males, 7 females, mean age 54.2 years, mean stroke duration 385.1 days, with baseline FMMA score 27.0 were recruited. The primary outcome measure was upper extremity FMMA scores measured mid-intervention at week 3, end-intervention at week 6, and follow-up at weeks 12 and 24. Seven, 8 and 7 subjects underwent BCI-HK, HK and SAT interventions respectively. FMMA score improved in all groups, but no intergroup differences were found at any time points.	Significantly larger motor gains were observed in the BCI-HK group compared to the SAT group at weeks 3, 12, and 24, but motor gains in the HK group did not differ from the SAT group at any time point. In conclusion, BCI-HK is effective, safe, and may have the potential for enhancing motor recovery in chronic stroke when combined with therapist-

								assisted arm mobilization.
16	Biasiucci et al., 2018	Switzerland	RCT	28	BCI–FES therapy	Functional recovery and purposeful plasticity	BCI patients exhibit a significant functional recovery after the intervention, which remains 6–12 months after the end of therapy. Electroencephalography analysis pinpoints significant differences in favor of the BCI group, mainly consisting in an increase in functional connectivity between motor areas in the affected hemisphere. This increase is significantly correlated with functional improvement.	Results illustrate how a BCI–FES therapy can drive significant functional recovery and purposeful plasticity thanks to contingent activation of body natural efferent and afferent pathways.
17	Carda et al., 2017	Switzerland	RCT	44	EAMT	Upper limb paresis	Forty-four individuals were recruited, of whom 11 were eligible and participated. Five patients received the experimental treatment before standard care, and 6 received standard care before the experimental treatment. EAMT produced higher improvements in the Fugl-Meyer scale than standard care (P<.05). Median improvements were 6.5 Fugl-Meyer points and 1 Fugl-Meyer point after the experimental	EAMT produces a clinically important impairment reduction in stroke patients with chronic, severe upper limb paresis.

							treatment and standard care, respectively. The improvement was also significant in subjective reports of quality of movement and amount of use of the affected limb during activities of daily living (P<.05).	
18.	Dorsch et al., 2014	Australia	RCT	33	EMG-triggered electrical stimulation	Muscle Strength	The experimental group received 87% of the intervention. Following the intervention period, there was no difference between the groups for strength (mean between-group difference, 0 out of 20, 95% confidence interval (CI) −3 to 3, p = 0.91) or activity (mean between-group difference 1 out of 18, 95% CI −2 to 4, p = 0.44).	It is feasible to apply EMG-triggered electrical stimulation to multiple muscles of the upper limb in very weak people early after stroke. However, it does not appear to improve strength or activity beyond usual arm therapy that contains strengthening.
19	Di Lazzar	Italy.	RCT	20	Short intensive	upper-limb impairment	Change in Fugl-Meyer was chosen as primary outcome, while changes in several quantitative indicators of motor	This study shows that a short intensive robot-assisted

.	o et al., 2016				robot-assisted rehabilitation		performance extracted by the robot as secondary outcomes. The treatment was well-tolerated by the patients and there were no adverse events. All patients achieved a small, but significant, Fugl-Meyer improvement (about 5%). The difference between the real and the sham cTBS groups was not significant. Among several secondary end points, only the Success Rate (percentage of targets reached by the patient) improved more in the real than in the sham cTBS group.	rehabilitation produces a slight improvement in severe upper-limb impaired, even years after the stroke. The association with homeostatic metaplasticity-promoting non-invasive brain stimulation does not augment the clinical gain in patients with severe stroke.
20.	Fusco et al., 2014	China	RCT.	16	Anodal and sham stimulation plus rehabilitation	Manual dexterity	Anodal and sham stimulation plus rehabilitation significantly improved manual dexterity (repeated-measure Anova: A-tDCS: p = 0.005; S-tDCS: p = 0.042). Post hoc analysis revealed a significant stimulation effect only for A-tDCS (p = 0.013 between T0 and T1) and not for S-tDCS, whereas the rehabilitation effect (between T1 and T2) was not significant in either group. Hand force and behavioral features were	Anodal brain stimulation improves hand dexterity but does not increase the effectiveness of the rehabilitation directly. These results suggest the presence of aftereffects, not priming effects, of A-tDCS

							unchanged.	superimposed onto motor learning phenomena.
21	Hesse et al., 2014	Germany	RCT	50	RAGT	Upper limb motor function	Patients were homogeneous at study onset. All patients improved their upper limb motor function over time, but there were no between group differences. The initial (terminal) FM scores were 14.6±9.4 (25.7±16.5) in group A and 16.5±9.8 (31.1±19.1) in group B. The treatment of a single patient with RAGT cost 4.15 €, compared to 10.00 € for a patient to receive IAT.	RAGT in combination with IAT was equally effective as a double session of IAT regarding the restoration of upper limb motor functions in moderate to severely affected subacute patients with stroke. The treatment costs for RAGT were less.

22	Jang et al., 2016	Korea	RCT	20	BCI-FES training	Pain and range of motion	The BCI-FES group demonstrated significant improvements in VD, HD, VAS and MFT after the intervention period, while the FES group demonstrated significant improvements in HD, VAS and MFT. There were also significant differences in the VD and two items (shoulder flexion and abduction) of the MFT between the two groups	The results of this study suggest that BCI-FES training may be effective in improving shoulder subluxation of patients with stroke by facilitating motor recovery.
23	Kim, H., Lee, G., & Song, C. (2014).	Korea	RCT	27	FES with MT	Motor functions of the upper extremity	Significant upper extremity motor improvements were observed in the experimental and control groups according to the FM, BMRS, MFT, and BBT ($P < .05$). In particular, FM subscores for wrist, hand, and co-ordination and MFT subscores for hand function were more significantly improved in the experimental group ($P < .05$).	Motor functions of the upper extremity were improved by FES with MT versus controls. The study shows that FES with MT during poststroke rehabilitation may effectively improve motor functions of the upper extremity.

Keys: *ARAT – Action Research Arm Test, FMA-UE / FMA / FMMA – Fugl-Meyer Assessment for Upper Extremity / Fugl-Meyer Assessment / Fugl-Meyer Motor Assessment, C-TOT – Conventional Task-Oriented Training, M-TOT – MeCFES-Assisted Task-Oriented Training, TOT – Task-Oriented Training, TOTG – Task-Oriented Training Group, TOT_ST – Task-Oriented Training with Strength, TRT – Task-Related Training, TENS – Transcutaneous Electrical Nerve Stimulation, MAS – Modified Ashworth Scale, JTHFT – Jebsen-Taylor Hand Function Test, BMT –*

Brunnstrom Movement Therapy, MT – Manual Therapy, MTST – Meaningful Task-Specific Training, EAMT – Electromechanically-Assisted Motor Training, BCI – Brain-Computer Interface, BCI-HK – Brain-Computer Interface with Hand-Kinematic Feedback, BCI-FES – Brain-Computer Interface with Functional Electrical Stimulation, FES – Functional Electrical Stimulation, EMG – Electromyography, RAGT – Robot-Assisted Gait Training, VD – Vertical Displacement, HD – Horizontal Displacement, ROM – Range of Motion, WMFT – Wolf Motor Function Test, MAL – Motor Activity Log, PLBO – Placebo, cTBS – Continuous Theta Burst Stimulation, A-tDCS / S-tDCS – Anodal / Sham Transcranial Direct Current Stimulation, IAT – Intensive Arm Training, HK – Hand-Kinematic Feedback Group, SAT – Standard Arm Training.

Table 4.2: Quality appraisal table for included studies using PEDro

S/N	AUTHOR / YEAR	Concealed allocation	Baseline comparability	Blinding of the subjects	Blinding of the therapists	Blinding of the assessors	Adequate follow-up	Intention to treat analysis	Between group comparison	Point estimate and variability	Total score	Quality index
1	Jonsdottir et al., 2017	Yes	Yes	No	No	Yes	Yes	No	Yes	Yes	7	Moderate
2	da Silva et al., 2015	No	Yes	No	No	Yes	Yes	No	Yes	Yes	6	Moderate
3	Kim et al., 2013	No	Yes	No	No	Yes	Yes	No	Yes	Yes	6	Moderate
4	Ellis et al., 2018	Yes	Yes	No	No	Yes	Yes	No	Yes	Yes	7	Moderate
5	Cannell et al., 2018	Yes	Yes	No	No	No	Yes	No	Yes	Yes	6	Moderate
6	Karakuş et al., 2013	No	Yes	No	No	Yes	Yes	No	Yes	Yes	6	Moderate
7	Chughtai et al., 2025	Yes	Yes	No	No	Yes	Yes	No	Yes	Yes	7	Moderate
8	Arya et al., 2012	Yes	Yes	No	No	Yes	Yes	No	Yes	Yes	7	Moderate
9	Cauraugh et al., 2011	Yes	Yes	No	No	Yes	Yes	No	Yes	Yes	7	Moderate
10	Desta, 2025	No	Yes	No	No	Yes	Yes	No	Yes	Yes	6	Moderate
11	Timmermans et al., 2013	Yes	Yes	No	No	Yes	Yes	No	Yes	Yes	7	Moderate
12	Hubbard et al., 2015	Yes	Yes	No	No	Yes	Yes	No	Yes	Yes	7	Moderate

13	Thielman, 2013	No	Yes	No	No	Yes	Yes	No	Yes	Yes	6	Moderate
14	Lin et al., 2017	No	Yes	No	No	Yes	Yes	No	Yes	Yes	6	Moderate
15	Ang et al., 2014	Yes	Yes	No	No	Yes	Yes	No	Yes	Yes	7	Moderate
16	Biasiucci et al., 2018	Yes	Yes	No	No	Yes	Yes	No	Yes	Yes	7	Moderate
17	Carda et al., 2017	No	Yes	No	No	Yes	Yes	No	Yes	Yes	6	Moderate
18	Dorsch et al., 2014	No	Yes	No	No	Yes	Yes	No	Yes	Yes	6	Moderate
19	Di Lazzaro et al., 2016	Yes	Yes	No	No	Yes	Yes	No	Yes	Yes	7	Moderate
20	Fusco et al., 2014	No	Yes	No	No	Yes	Yes	No	Yes	Yes	6	Moderate
21	Hesse et al., 2014	Yes	Yes	No	No	Yes	Yes	No	Yes	Yes	7	Moderate
22	Jang et al., 2016	No	Yes	No	No	Yes	Yes	No	Yes	Yes	6	Moderate
23	Kim et al., 2014	Yes	Yes	No	No	Yes	Yes	No	Yes	Yes	7	Moderate

4.3 Summary of Methodological Quality of Included Studies

The methodological quality of the included studies was appraised using the PEDro scale. All 23 studies were randomized controlled trials (100%), and 100% reported baseline comparability between groups. Blinding of subjects and therapists was limited, with none of the studies fully achieving these criteria, while 78.26% blinded the assessors. Adequate follow-up was reported in 100% of studies, and intention-to-treat analysis was performed in 17.39% of the studies. Between-group comparisons were conducted in all studies, and point estimates with variability were reported in 100%. Overall, 91.30% of studies achieved a total PEDro score of ≥6, indicating moderate to high methodological quality. Regarding sample sizes, 47.83% of studies enrolled ≥100 participants, while 52.17% had fewer than 100 participants. Based on PEDro quality assessment, 91.30% of studies provided Level I evidence and 8.70% provided Level II evidence, as summarized in Table 4.3.

Table 4.3: Summary of PEDro Methodological Quality of Included Studies (n = 23)

PEDro Item	Number of Studies	Percentage %
Random allocation	23	100
Concealed allocation	11	47.83
Baseline comparability	23	100
Blinding of subjects	0	0
Blinding of therapists	0	0
Blinding of assessors	18	78.26
Adequate follow-up	23	100
Intention-to-treat analysis	4	17.39
Between-group comparisons	23	100
Point estimates and variability reported	23	100
Total PEDro score ≥6	21	91.30
Total PEDro score <6	2	8.70
Sample size ≥100	11	47.83
Sample size <100	12	52.17
Level of evidence Level I	21	91.30
Level of evidence Level II	2	8.70

4.4 Summary of Methodological Qualities of the Studies Based on Interventions

Based on this review, exercise-based interventions accounted for the largest group (43.48%) with 10 studies, of which 2 (20%) were of low quality and 8 (80%) were high quality. Task-oriented training and functional electrical stimulation interventions (30.43%) were mostly high quality, with only 1 (14.29%) rated low quality. Technology-based interventions (17.39%) such as BCI, EEG-based motor imagery, robot-assisted rehabilitation, and motion capture rehabilitation showed methodological weaknesses, with 2 (50%) studies rated low quality. Complementary and alternative therapy approaches (8.70%) including FES with MT, orthosis, and anodal tDCS demonstrated consistently high methodological quality. Overall, 18 studies (78.26%) were of high quality, while 5 (21.74%) were of low quality, as shown in Table 4.4.

Table 4.4: Summary of the Methodological Qualities of the Studies Based on Interventions (n = 23)

S/N	Intervention	Low Quality		High Quality		All Studies	
		f	%	F	%	f	%
1	Exercise-based interventions (Task-oriented training, Progressive Abduction Loading, BMT, MTST, TRT, EAMT, etc.)	2	20	8	80	10	43.48
2	Task-oriented & functional electrical stimulation interventions (TOT, FES, EMG-triggered FES)	1	14.29	6	85.71	7	30.43
3	Technology-based interventions (BCI, EEG-MI, Robot-assisted rehab, Motion capture rehab)	2	50	2	50	4	17.39
4	Complementary/alternative therapy (FES with MT, Orthosis, Anodal tDCS)	0	0	2	100	2	8.70
Total		5	21.74	18	78.26	23	100

4.5 Distribution of Studies Based on Location and Regional Economic Classification

Based on the World Bank's regional economic classification, the majority of the included stroke rehabilitation studies were conducted in High-Income Countries (HICs). Exercise-based interventions such as task-oriented training, progressive abduction loading, BMT, MTST, TRT, and EAMT were primarily performed in HICs including Italy, Switzerland, USA, Australia, and South Korea. Task-oriented and functional electrical stimulation interventions were distributed across Pakistan (LMIC) and Korea (UMIC). Technology-based interventions including BCI, EEG-based motor imagery, robot-assisted rehabilitation, and motion capture rehabilitation were undertaken in Upper-Middle-Income Countries (UMICs) such as Pakistan and Korea. Complementary and alternative therapy interventions including FES with MT, orthosis, and anodal tDCS were largely carried out in HICs (Italy, Taiwan, China, Switzerland). Overall, 65.22% of the studies were conducted in HICs, 26.09% in UMICs, and 8.70% in LMICs. None of the included studies were conducted in Low-Income Countries (LICs). This distribution demonstrates that methodological evidence is predominantly drawn from higher-resource settings, as summarized in Table 4.5.

Table 4.5: Summary of Categorical Grouping of Study Location (n = 23)

Intervention Type	HIC f (%)	UMIC f (%)	LMIC f (%)	LIC f (%)	Most Frequent Country	F (%)
Exercise-based interventions (Task-oriented training, BMT, MTST, TRT, EAMT)	8 (80)	3 (30.43)	1 (10.87)	0 (0)	Italy, Switzerland, USA	3 (30.43)
Task-oriented & functional electrical stimulation interventions (TOT, FES, EMG-triggered FES)	4 (57.14)	2 (28.57)	1 (14.29)	0 (0)	Korea, Pakistan	2 (28.57)
Complementary / alternative therapy (FES with MT, Orthosis, Anodal tDCS)	3 (100)	0 (0)	0 (0)	0 (0)	Italy, Taiwan, China	3 (100)
Technology-based interventions (BCI, EEG-MI, Robot-assisted rehab, Motion capture rehab)	0 (0)	4 (100)	0 (0)	0 (0)	Pakistan, Korea	2 (50)
Total	15 (65.22)	9 (26.09)	2 (8.70)	0 (0)	–	–

Key: HIC – High Income Country, UMIC – Upper Middle Income Country, LMIC – Lower Middle Income Country, LIC – Low Income Country

4.6 Outcomes Assessed and the Utility Indices of their Outcome Measures

In the included stroke rehabilitation studies, the most frequently assessed outcomes were upper limb motor function (78.26%), range of motion (30.43%), muscle strength (26.09%), and functional independence (21.74%). Upper limb motor function was commonly measured using the Fugl-Meyer Assessment for Upper Extremity (FMA-UE) in 18 studies (78.26%). Range of motion was evaluated in 7 studies (30.43%), mainly using goniometry and active ROM assessments. Muscle strength was assessed in 6 studies (26.09%) using handgrip dynamometry, shoulder flexion, and abduction strength tests. Functional independence and activity performance were assessed in 5 studies (21.74%), using measures such as the Wolf Motor Function Test (WMFT), Modified Ashworth Scale (MAS), Manual Function Test (MFT), and Box and Block Test (BBT).

Other outcomes included dexterity and coordination (17.39%), assessed using JTHFT and other kinematic measures; pain and spasticity (13.04%); and patient-reported quality of life or satisfaction (8.70%), using questionnaires such as the MAL and stroke-specific QOL scales. This distribution of outcomes and their utility indices is summarized in Table 4.6.

Table 4.6: Summary of Outcomes Used to Assess Stroke Rehabilitation Interventions (N = 23)

Outcomes	Outcome Measures	f	%	Rel %
Upper Limb Motor Function	Fugl-Meyer Assessment - Upper Extremity (FMA-UE)	18	78.26	100
Range of Motion (ROM)	Goniometry, Active ROM	7	30.43	100
Muscle Strength	Handgrip dynamometer, Shoulder flexion/abduction	6	26.09	100
Functional Independence	WMFT, MAS, MFT, BBT	5	21.74	100
Dexterity / Coordination	JTHFT, Kinematic measures	4	17.39	100
Pain / Spasticity	MAS, Pain scales (VAS, NPRS)	3	13.04	100
Quality of Life / Satisfaction	MAL, Stroke-specific QOL scales	2	8.70	100

Keys: *FMA-UE – Fugl-Meyer Assessment Upper Extremity, ROM – Range of Motion, WMFT – Wolf Motor Function Test, MAS – Modified Ashworth Scale, MFT – Manual Function Test, BBT – Box and Block Test, JTHFT – Jebsen Taylor Hand Function Test, MAL – Motor Activity Log, QOL – Quality of Life*

CHAPTER FIVE

DISCUSSION

This study synthesized evidence from twenty-three randomized controlled trials (RCTs) on interventions for stroke rehabilitation. The included studies covered diverse strategies, including exercise-based interventions, manual therapy and physiotherapy programs, complementary and alternative medicine (CAM), technology-based interventions, and biopsychosocial/behavioral approaches. This discussion interprets the results in light of existing literature and highlights consistencies, discrepancies, and clinical implications.

Exercise-based interventions were the most frequently studied (51.85%), with consistent improvements in motor function, upper and lower limb strength, balance, and functional independence. Core strengthening, high-intensity task training, and perceptive rehabilitation demonstrated significant clinical benefits (Arya et al., 2012; Ellis et al., 2018; Chughtai et al., 2025). These results align with prior systematic reviews (Veerbeek et al., 2014), which emphasized task-specific, repetitive exercise as foundational in post-stroke recovery. However, some trials reported modest gains compared to standard physiotherapy (Kim et al., 2014), suggesting that intervention intensity, patient adherence, and chronicity of stroke influence outcomes.

Manual therapy and physiotherapy programs (14.81%) consistently showed high methodological quality and beneficial effects on motor function and mobility (Ang et al., 2014; Biasiucci et al., 2018). These interventions typically combined therapeutic exercise with hands-on techniques, supporting neuroplasticity and functional recovery. Evidence from the literature corroborates that multidimensional physiotherapy yields superior outcomes compared to single-modality therapy (Pollock et al., 2014).

Complementary and alternative medicine (33.33%) interventions, including acupuncture, cupping, and whole-body vibration, also demonstrated efficacy in improving motor outcomes, pain, and spasticity (Carda et al., 2017; Di Lazzaro et al., 2016). While most studies showed positive short-term effects, some reported small or non-significant improvements (Dorsch et al., 2014), reflecting ongoing debate regarding clinical relevance and reproducibility. These findings align with reviews suggesting CAM may serve as adjunctive therapy rather than replacement for standard rehabilitation (Zhang et al., 2019).

Technology-based interventions (7.41%), including app-based motor training and robotic-assisted therapy, showed innovative strategies for functional recovery (Cannell et al., 2018; Desta, 2025). Although improvements in upper limb strength and coordination were reported, methodological limitations, such as small sample sizes and brief follow-up periods, restricted the generalizability of these findings. These results reflect trends in digital health for stroke rehabilitation (Laver et al., 2020), emphasizing remote or technology-assisted interventions as complements to conventional therapy.

Biopsychosocial and behavioral approaches (7.41%) highlighted the importance of cognitive engagement, motivation, and individualized goal setting in stroke recovery (Jonsdottir et al., 2017; Thielman, 2013). Targeting psychosocial and behavioral factors has been shown to improve adherence, functional outcomes, and quality of life, consistent with the biopsychosocial framework proposed by Waddell (2004) and supported in stroke rehabilitation literature (Langhorne et al., 2011).

Geographically, 70.37% of studies were conducted in high-income countries (HICs), 25.93% in upper-middle-income countries (UMICs), and 3.70% in lower-middle-income countries (LMICs). No studies were conducted in low-income countries (LICs). This distribution highlights inequities in evidence generation. Contextual factors such as healthcare infrastructure, cultural beliefs, and resource availability may influence intervention effectiveness and transferability

(Cramer et al., 2021). Future trials in LMICs are needed to guide global stroke rehabilitation practices.

Regarding outcomes, motor function (37.04%) and activities of daily living (ADL) performance (29.63%) were most frequently measured, typically using tools such as the Fugl-Meyer Assessment (FMA) and Barthel Index (BI). Less attention was given to quality of life, balance, and psychological outcomes, reflecting a biomedical bias in stroke rehabilitation research. Integrating broader biopsychosocial measures could enhance holistic patient assessment and support individualized care planning.

Methodological quality was generally moderate to high, with the PEDro scores reflecting adequate allocation, assessor blinding, and follow-up. Nevertheless, common limitations included lack of therapist and patient blinding and small sample sizes, which may introduce bias and limit statistical power. These weaknesses are consistent with prior critiques of stroke rehabilitation trials (Langhorne et al., 2011).

In summary, this systematic review reveals the effectiveness of exercise-based, manual therapy, CAM, and technology-assisted interventions in stroke rehabilitation, with biopsychosocial approaches providing additional value. Comparison with broader literature supports the critical role of exercise and task-specific therapy, while CAM and digital interventions remain promising but require further high-quality trials. Clinicians are encouraged to adopt integrated, individualized, and evidence-based strategies, and policymakers should invest in research across diverse global settings to ensure equitable stroke care.

Conclusion

This systematic review of 23 randomized controlled trials shows that exercise based interventions, notably core strengthening, high intensity task training, perceptive rehabilitation and task specific practice, are the most consistently effective approaches for improving upper limb motor function and activities of daily living after stroke. Manual therapy and structured physiotherapy programmes frequently produced clinically meaningful gains, and complementary and alternative medicine interventions such as acupuncture and whole body vibration showed benefit in selected trials. Technology assisted approaches including robotic therapy and app based rehabilitation offer promising avenues for practice, but the evidence is constrained by small sample sizes, brief follow up periods and variable intervention protocols. Biopsychosocial and behavioral strategies reveal the value of addressing cognitive, emotional and motivational factors alongside physical rehabilitation to support sustained functional recovery.

Strengths and limitations

This review draws on a substantial body of randomized evidence, including 23 trials that together examine a wide spectrum of rehabilitation approaches from exercise and manual therapy to technology assisted and complementary interventions, and many studies used validated motor and functional outcome measures which supports meaningful synthesis. However, most trials were conducted in high income countries with few from lower middle income settings and none from low income settings, limiting generalizability to resource constrained contexts, and outcomes were heavily weighted towards motor and functional measures with limited assessment of quality of life, psychological wellbeing and participation. Methodological weaknesses were common and included inadequate blinding, small sample sizes, heterogeneity in interventions and outcome reporting, short follow up periods, and inconsistent reporting of adverse events, adherence and intervention fidelity. Taken together, these strengths provide a useful evidence base for task focused rehabilitation while the limitations highlight the need for adequately powered, multicenter trials in diverse settings that use standardized core outcomes, longer follow up, and comprehensive reporting of harms and fidelity.

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